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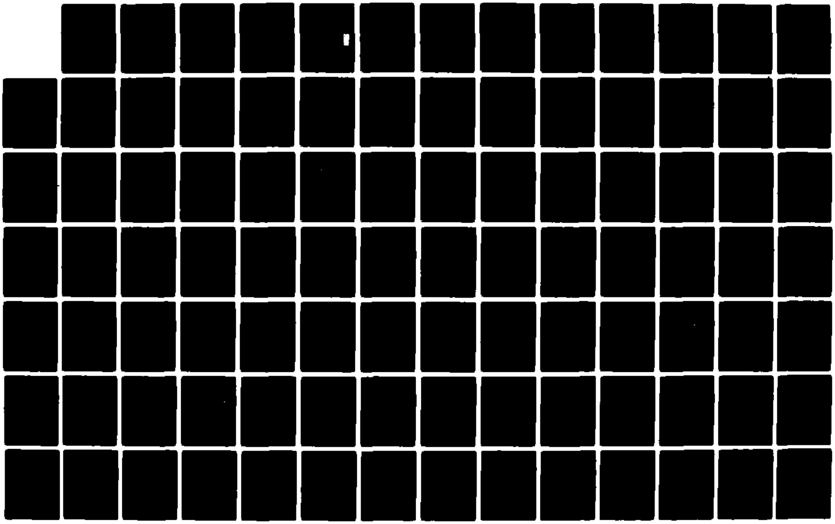

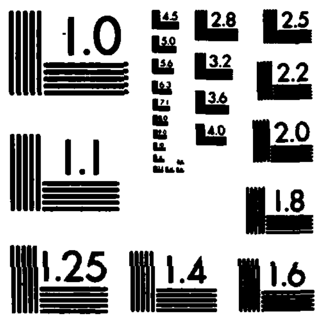

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Name: Gregory Edward Riggs Date of Degree: December, 1982

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: ANALYSIS OF PROGRESSIVE COLLAPSE OF COMPLEX STRUCTURES

Pages in Study: 192 Candidate for Degree of Doctor of Philosophy

Major Field: Civil Engineering

Scope and Method of Study: The principal goal of the study was to evaluate an analytical procedure for predicting progressive collapse in damaged complex structures. A structure was modeled for analysis by the finite element method using relatively large, simple elements. There was little or no refinement of mesh size in areas of initial damage or damage propagation. A method was developed for determining and applying allowable stresses to help compensate for the absence of model detail. Stress results of a finite element analysis were examined by a computer post-processor program written for this study to make selective changes to the finite element model. The modified model was analyzed using the finite element method and the procedure was repeated in an iterative fashion to predict progressive collapse. Analytical results were compared to experimental test data to determine the validity of the analytical procedure.

Findings and Conclusions: The analytical procedure provided a relatively economical method for predicting progressive collapse in a complex structure. Evaluation of a complex structure subjected to three initial damage conditions showed acceptable correlation between experimental and analytical results. The method of determining appropriate allowable stresses was general enough to apply to a wide range of materials and structures. The procedure proved to be an economical estimating tool for predicting residual structural strength.

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ANALYSIS OF PROGRESSIVE COLLAPSE

OF COMPLEX STRUCTURES

By

GREGORY EDWARD RIGGS

Bachelor of Science in Civil Engineering
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Colorado Springs, Colorado
1972

Master of Science
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1973

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
December, 1982

ANALYSIS OF PROGRESSIVE COLLAPSE

OF COMPLEX STRUCTURES

Thesis Approved:

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Thesis Adviser

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Dean of the Graduate College

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Of the many people deserving acknowledgment, it is appropriate that the first to receive thanks is Dr. Allen E. Kelly. As major adviser and chairman of my committee, he maintained a delicate balance between providing general guidance and giving full rein for me to travel my own course and learn along the way. I thank Dr. Thomas D. Jordan, a committee member, for providing background information concerning the formulation of the F-84F wing finite element model. I thank them and the other members of my committee, Dr. William P. Dawkins, Dr. John W. Harvey, and Professor Louis O. Bass, Jr., for their willingness to interrupt their own work at any time to discuss with me various aspects of the study.

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Ms. Charlene Fries receives thanks from students every semester for typing manuscripts, but such thanks severely underrate her contributions. She assumes full responsibility for administering the preparation and submission of the documents. I certainly thank her.

My wife, Jan, deserves a special thanks for her part in this program. She provided all of the encouragement and support, including assuming many of my responsibilities within our home, typical of any loving spouse behind a doctoral candidate. Beyond that, she demonstrated the analytical talents needed to assist me in portions of my course work and to recommend improvements to my research. I also thank my two young daughters, Megan and Michele, who donated a portion of their rightful time with their father during the last three months of the study.

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CHAPTER I

INTRODUCTION

Many structures are susceptible to progressive collapse, a chain reaction type of failure following damage to a relatively small portion of the structure. The more specialized a structure is, the more vulnerable it is to progressive failure largely because it is designed to resist fewer possible loading conditions. As efforts increase to optimize designs within acceptable factors of safety, the risks of initiating progressive collapse through relatively minor localized damage also increase. An ability to predict analytically the response of a damaged structure would therefore be beneficial.

Although progressive collapse is normally associated with high-rise buildings, interest in it is not limited to conventional civil engineering applications. The Department of Defense needs the capability to predict the residual strength of battle-damaged aircraft and to know the role of progressive collapse in that setting. Specifically, the Department of Defense Joint Technical Coordinating Group for Munitions Effectiveness is interested in the post-damaged capabilities of potentially hostile aircraft.

In pursuit of its interest, the Group provided research funds and three F-84F aircraft wings for this study. The goal was to evaluate a potentially versatile method for predicting progressive collapse in aircraft structures. The method was to be verified by experimental testing.

Desirable characteristics to be imparted to the method would be relative simplicity in preparing for its use and relative ease and economy in its application.

The finite element method was the fundamental tool for determining stresses within the wing. In this report most discussion of the finite element method is of a general nature. The NASTRAN (National Aeronautical and Space Administration Structural Analysis) program was selected to apply the finite element method because of its versatility and its widespread availability in both industry and the defense community. The reader is assumed to be familiar with the finite element method in general. Where reference to specific program characteristics is essential, a basic familiarity with NASTRAN is also assumed.

Finally, the sponsor of this research is interested in the effectiveness of munitions in destroying combat aircraft. Consequently, any conservative assumption is one which tends to give the structure more strength than actually exists. This definition of conservative is used throughout the study. Caution must be exercised in directly extending the results of this study to more conventional applications. In such use the assumptions of this study would become unconservative.

CHAPTER II

LITERATURE REVIEW

2.1 General

Many papers have addressed the topic of progressive collapse of damaged structures, but only one has provided a general quantitative method of analysis (1). The following sections summarize the published papers while the last section details the one general approach.

2.2 Qualitative Analysis

Most studies of progressive collapse, as applied to structures conventionally associated with Civil Engineering, fit into three categories. The first addressed a need to predict statistically the frequency and severity of damaging events such as vehicle impact or explosion (2 through 8).

Another category was the qualitative analysis of a structure's ability to resist damage or to develop alternate load paths around damage. Typical topics of discussion included catenary action of slabs, beam action of adequately tied ceiling-wall-floor systems acting as wide flange sections, and the in-plane arching of walls over damage (4, 7, 9 through 14).

A third category was an effort to develop codes which mate the first two areas into economically and socially acceptable guidelines for design and construction (15 through 23). Additionally, a research workshop was

conducted in 1975 to evaluate present knowledge of the progressive collapse phenomenon and to identify areas requiring further study (24).

2.3 Quantitative Analysis of Building Structures

A smaller, fourth category addressed the need to evaluate quantitatively the behaviors occurring during a progressive collapse. Several studies have been completed, but most have considered only two-dimensional problems and most have required extensive analyst interactive involvement (25 through 29).

Smith and Epstein (30) developed a three-dimensional method to analyze the progressive collapse of a space truss roof. Their approach used the finite element method to determine structural member stresses. As a member approached its buckling load, predetermined for every member in the structure, the member was replaced by opposite equal forces representing post-buckling strength. The method did provide a three-dimensional analysis but was limited exclusively to buckling related failures. It was inappropriate for structures in which other failure modes share equal importance or are dominant.

2.4 Quantitative Analysis of Aircraft Structures

The military's need to predict the behavior of damaged aircraft has precipitated several papers of interest. Venkayya (31) outlined an empirical iterative procedure in 1978 for determining the residual strength of damaged structures. The displacements and decomposed stiffness matrix of an undamaged structure were combined with a sparse negative stiffness matrix representing damage. The result was an iteratively derived second-order Taylor series approximation of the response of the damaged structure.

The method appeared suitable for economic evaluation of initial structure response to several different damage conditions. However, when the method is applied to progressive collapse analyses, problems surface as component failure progresses toward collapse. Solution convergence times become unacceptably slow and convergence criteria become increasingly difficult to establish.

In 1976, Heard (1) proposed for the Air Force Armaments Testing Laboratory (AFATL) a method of structural modeling and analysis for progressive collapse in aircraft structures. That method, referred to in this study as the AFATL method, appeared to be the most promising general approach to a quantitative analysis of progressive collapse. The next section presents this method in some detail.

2.5 Analysis Method Background

The structure being evaluated must be represented as a computer model for finite element analysis. Because the method requires many iterative analyses to trace the progressive collapse phenomenon, economy urges the use of the largest, simplest elements which still describe the basic geometry of the structure and provide adequate precision to permit a stress-based analysis. A principal feature of the AFATL method is that little or no refinement of the model occurs in the area of damage. This feature aids the economy of the method but, because the large elements mask stress concentrations, the method must include compensating techniques. Heard employed two such techniques which are described later.

A load was applied to the model and the resulting stresses were examined in search of overstressed elements. An overstressed element was one whose stresses exceeded predefined limiting values. A solitary over-

stressed element was removed from the model as having failed. If more than one overstressed element occurred grouped together, only the most severely stressed element of the group was removed. This technique helped represent crack propagation in a model composed of large elements and was supported by studies of Sih and Hartranft (28).

Reducing the values of limiting stresses for elements bordering damage was the second technique to compensate for loss of stress concentrations around crack tips at the edges of damage. Thus the computed stress in an element bordering damage might produce element failure while a similarly stressed element away from damage remained intact. Using different values for limiting stresses complicated the process of selecting which element to fail in a group of overstressed elements. The most severely stressed element could not be determined through a direct comparison of the magnitudes of element stresses.

After the failed elements were removed, the modified model was again analyzed and the procedure was repeated. Iterations continued until the model could sustain some desired maximum load, or until failure occurred. This latter condition was sometimes determined subjectively by evaluating the structure's displaced shape rather than by its residual load-carrying capacity.

CHAPTER III

SPECIFIC OBJECTIVES

The method proposed by Heard appeared to be a versatile approach for the quantitative analysis of progressive collapse. To increase the acceptability of the method, however, four areas were identified as objectives for further study.

Validation of the method was perhaps the most important objective. Due to an absence of actual aircraft wings which his model represented, Heard was unable to substantiate with actual test data the value of his work. The first phase of this study was a laboratory test program which provided data for evaluation of analytical results. Tests of three F-84F aircraft wings measured structural performance under different damage and load combinations.

In the previous study, only one combination of elements was used for modeling the aircraft wing structure. A comparison of several element combinations was made in search of the best selection of model elements.

The actual application of the method required a great amount of manual data analysis for each iteration. A large number of elements had to be checked and compared to limiting stress values. The relative locations of overstressed elements had to be determined and caution applied to remove the appropriate element. Finally, removal of failed elements required modifications of the model. In addition to removing the failed elements, modification included reducing limiting stresses for elements

bordering the newly propagated damage. Automating the application of the method was desirable to reduce both time and expense for a complete analysis.

The final area to address was the appropriate values for limiting stresses. Heard used two levels of limiting stresses: material ultimate strength for elements away from damage, and material yield strength for elements bordering damage. A more sophisticated determination of limiting stresses had the potential for returning more realistic results.

These four areas,

1. Comparison of analytical and test results
2. Comparison of modeling elements
3. Automation of the method
4. Determination of limiting stress values,

became the specific objectives of this study.

CHAPTER IV

EXPERIMENTAL TEST PROGRAM

4.1 General

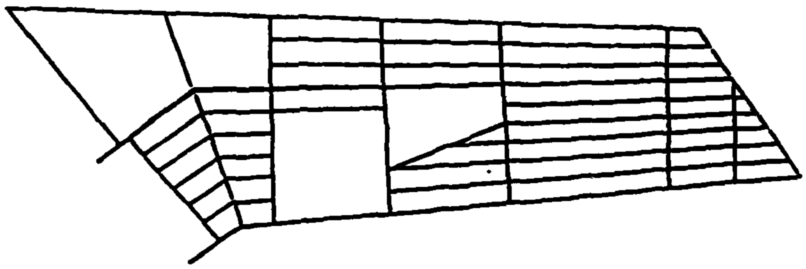
A major objective of this study was to use actual test data as a standard for evaluating analytical results. Three F-84F aircraft wings were tested, each with a different damage and load combination. This chapter contains descriptions of specific damage and loads and of the general test procedure. Appendix A contains diagrams showing strain gage locations for the various tests.

4.2 Specific Test Descriptions

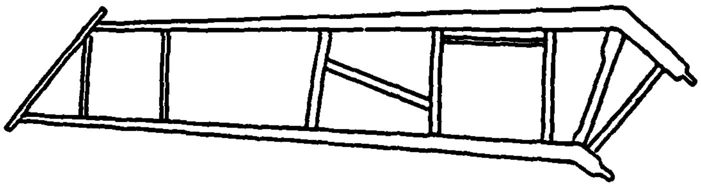
The F-84F aircraft wing is a two-spar, semi-monocoque structure. For general reference, Figure 1 illustrates the upper and lower wing surfaces and the wing structural frame. All three wings were mounted upside down for testing; however, the terms "upper" and "lower" refer to the wing's upper and lower surfaces, not to their physical orientation for the tests. For all tests, the landing gear and gear doors, flaps, and ailerons were removed.

Test 1 consisted of severe damage to the upper half of the front spar as shown in Figure 2. A load applied to the front spar produced a failure with bending as the predominant behavior. The damaged area was stressed in tension.

(a) Upper Surface



(b) Lower Surface



(c) Structural Frame

Figure 1. F-84F Wing Structure

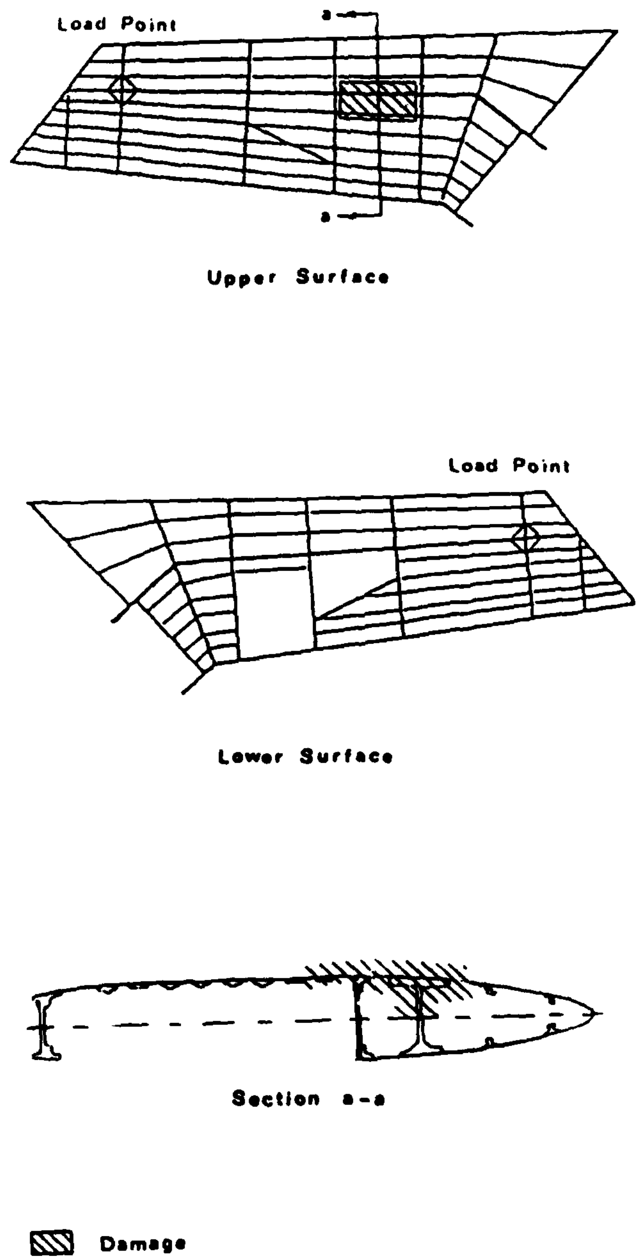


Figure 2. Damage for Test 1

Test 2, Figure 3, was to measure behavior with a significant amount of torsion present. The rear spar was completely severed and the load was applied to the rear spar. The result was a combination of bending and torsion in the front spar. This wing could not be failed within safe limits of the laboratory loading apparatus. Consequently, three loading trials were performed on this wing and designated Tests 2A, 2B, and 2C. Each test had slightly modified damage to the skin adjacent to the severed spar. These were efforts to initiate tearing of the skin over the wheel well area; however, no propagation of that damage occurred.

Test 3 was an attempt to represent more closely the damage which could occur from a shaped-charge missile warhead. Figure 4 shows a $5\frac{1}{2}$-inch wide strip of material removed from the lower wing surface. All skin was removed from the strip, which extended from the rear spar to the leading edge. The lower rear spar cap was removed but the web was left intact. The portion of the lower front spar cap extending from the web toward the trailing edge was also removed. The load applied to the rear spar put the damaged surface into compression.

The residual strength of this wing also exceeded the safe capacity of the loading equipment. A variation of this test, designated Test 3B, included further damage to the front spar cap. Half the width of the lower spar cap extending from the web toward the leading edge was removed. A $1\frac{1}{4}$-inch width of spar cap remained extending from the rear face of the web toward the leading edge. This additional damaoe led to complete structural failure.

4.3 Wing Support System

Each winq soar root mounted into a support structure as illustrated

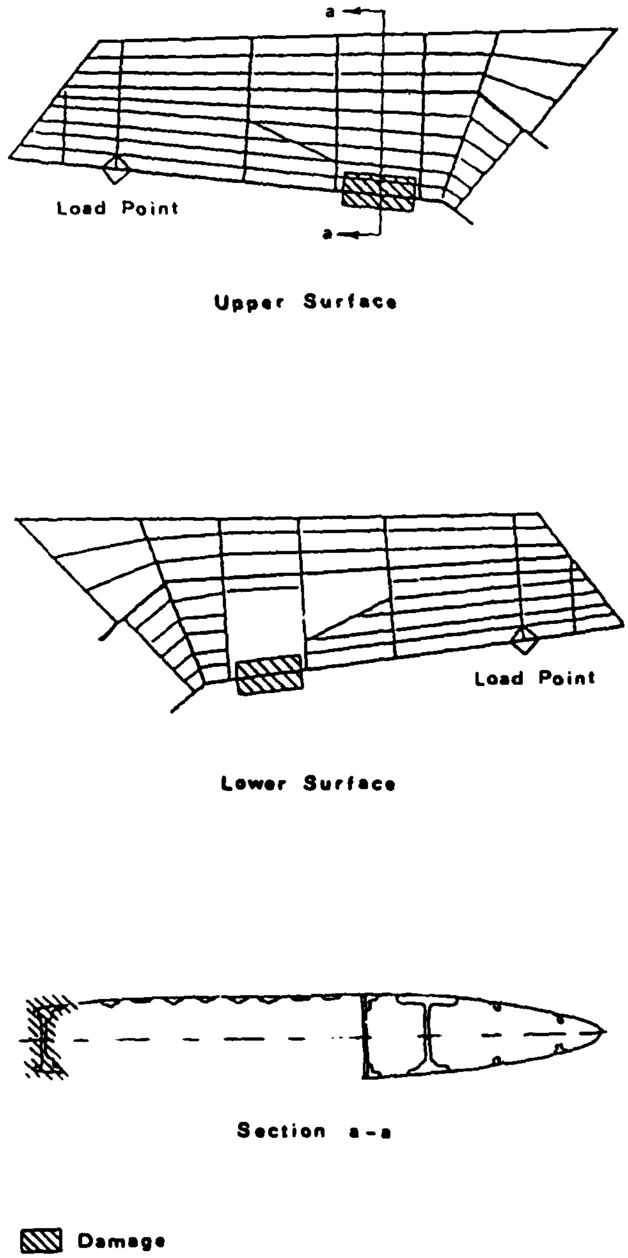


Figure 3. Damage for Test 2

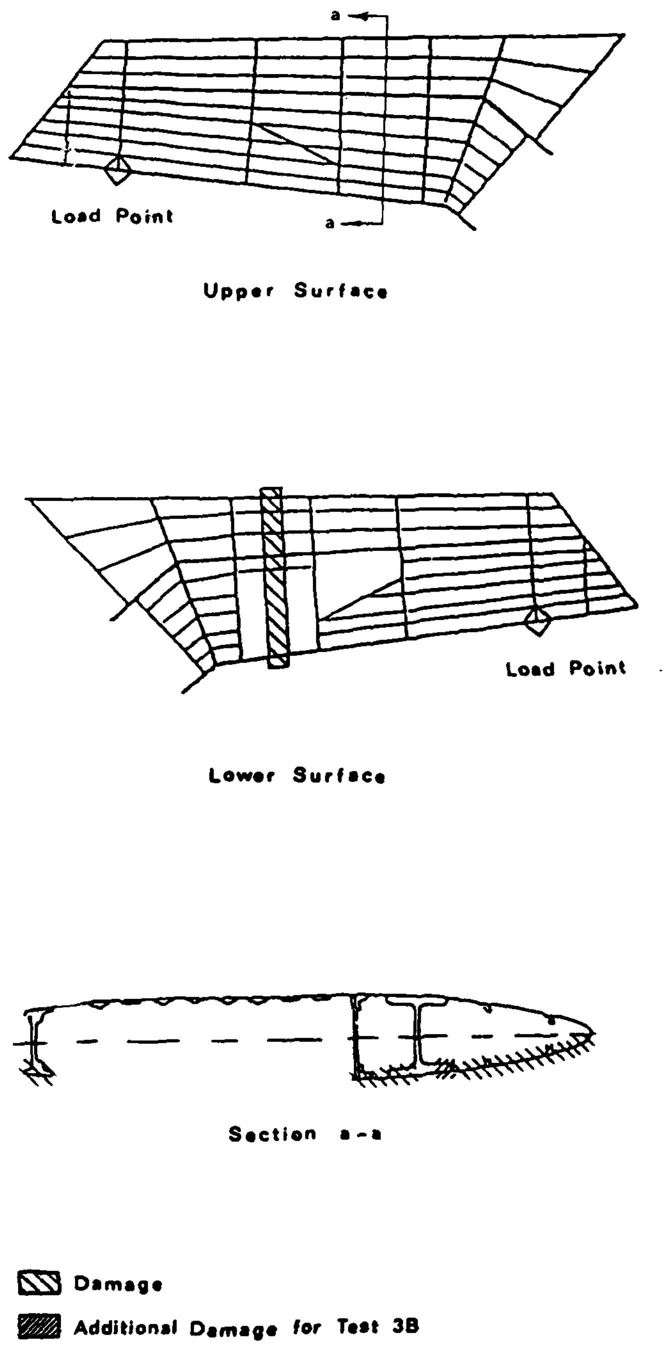


Figure 4. Damage for Test 3

in Figure 5. Pins secured the wings in the support structures in the same manner as the wings had been attached to aircraft fuselages. The support structures were extremely rigid compared to the wings so that no appreciable deformation occurred within the supports themselves. Three transducers supported each T-shaped support structure, permitting measurements of vertical reaction forces and reaction moments about two perpendicular horizontal axes.

The wing spar roots were aligned with the support structures and pinned into place within small tolerance; however, some motion of the wing spar roots with respect to the supports was unavoidable. For Tests 2 and 3, dial gages measured relative rotation of each wing spar root about horizontal axes parallel to and perpendicular to the root itself. These data then formed the basis for support conditions in corresponding finite element analyses. These support conditions provided a better analytical representation of wing deflections; however, support conditions assuming no relative rotation were used for stress analyses.

4.4 Load System

A movable overhead crane applied a single point load in each test. The crane was self-adjusting so the load was always applied vertically. A cable attaching the crane to the wing load point was equipped with an in-line transducer to permit continuous accurate monitoring of the actual load applied.

4.5 Deflection Measurements

Vertical deflections were measured at points along the front and rear spars corresponding to node points in the finite element model.

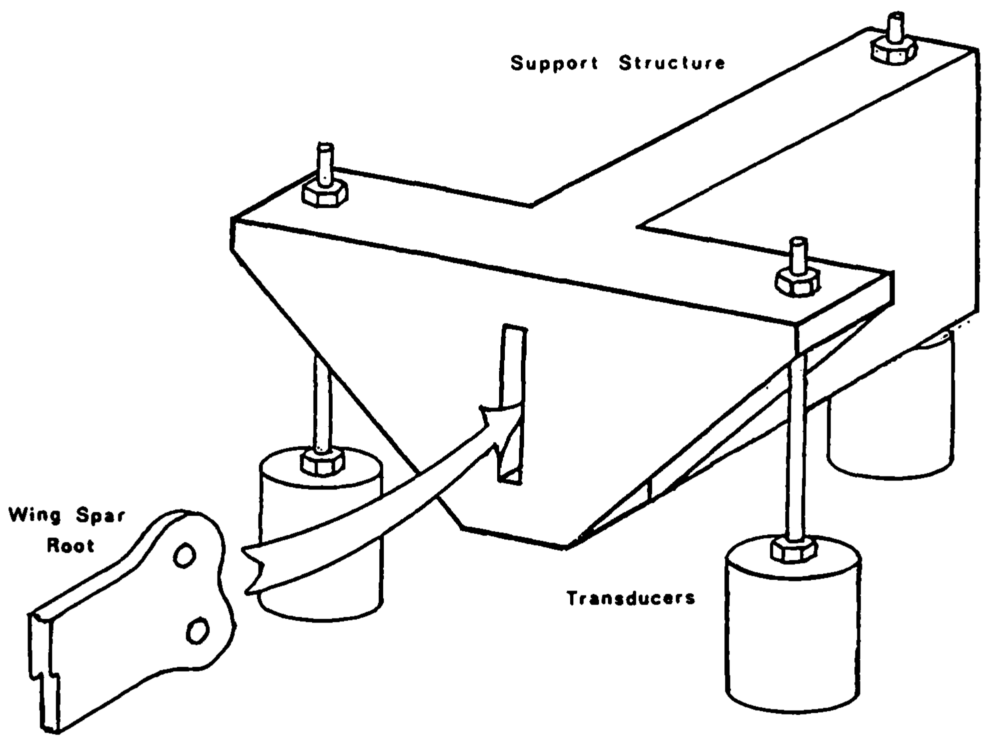


Figure 5. Wing Support Structure

Steel scales incremented to 0.01 inch were attached to the lower wing surface and measurements were read through an engineer's level. Similarly, scales were mounted on the support structures above each transducer to detect any vertical displacements there. At the load point no scale could be attached to the wing surface as at other locations along the spars. Instead, a cloth tape hung down vertically from the upper wing surface to measure deflections with respect to the laboratory floor.

4.6 Strain Measurements

Strain gages were mounted to the wing to detect changes in load paths as components failed and to detect load levels at which failures occurred. The different designs of each test and experience from previous tests led to slightly different strain gage placement for each wing. Appendix A contains specific locations.

Quarter-inch uniaxial strain gages measured outer fiber strains along spar and rib caps. Three-gage rectangular rosettes attached to selected skin panels measured panel behavior. Similar rosettes measured shear in rib and spar webs in Test 3.

Wings were first loaded enough to compensate for self-weight, and all gages were zeroed. For Test 1, all transducers and strain gages fed into a single switch and balance unit to measure output. All other tests used a Vishay Instruments Measurements Group computer-controlled data acquisition and reduction system. The System 4000 included the software program plus a Controller 4220 and two Strain Gage Scanners 4270. A Hewlett-Packard 9825B, upgraded to 9825T capabilities, served as the Executive Control Unit to complete the system hardware.

CHAPTER V

FINITE ELEMENT MODELS

5.1 Background

The fundamental modeling philosophy used by Heard (1) applied also to this study. Rod elements in combination with shear panels represented heavy structural members such as spars and ribs. Shear panel or membrane elements represented aircraft skin. Skin stiffeners were modeled by rod elements.

The specific structure for this study, the F-84F aircraft wing, was also analyzed by Jordan (32, 33). In 1976, he performed a dynamic response and small static load bending analysis of the wing. Although his objective differed from Heard's, he applied the same fundamental philosophy to develop his model of the wing. Jordan's model was the nucleus of the models evaluated in this study and is illustrated in Figure 6. Details of element numbering are presented in Appendix B.

The structure's geometry determined the size of the elements. Intersections of spars and ribs and of skin stiffeners and ribs were model node points. The node points in turn defined the elements. The procedure for assigning area properties for elements, particularly for rods, was detailed by both Heard (1) and Jordan (33). A brief summary is presented in Appendix C.

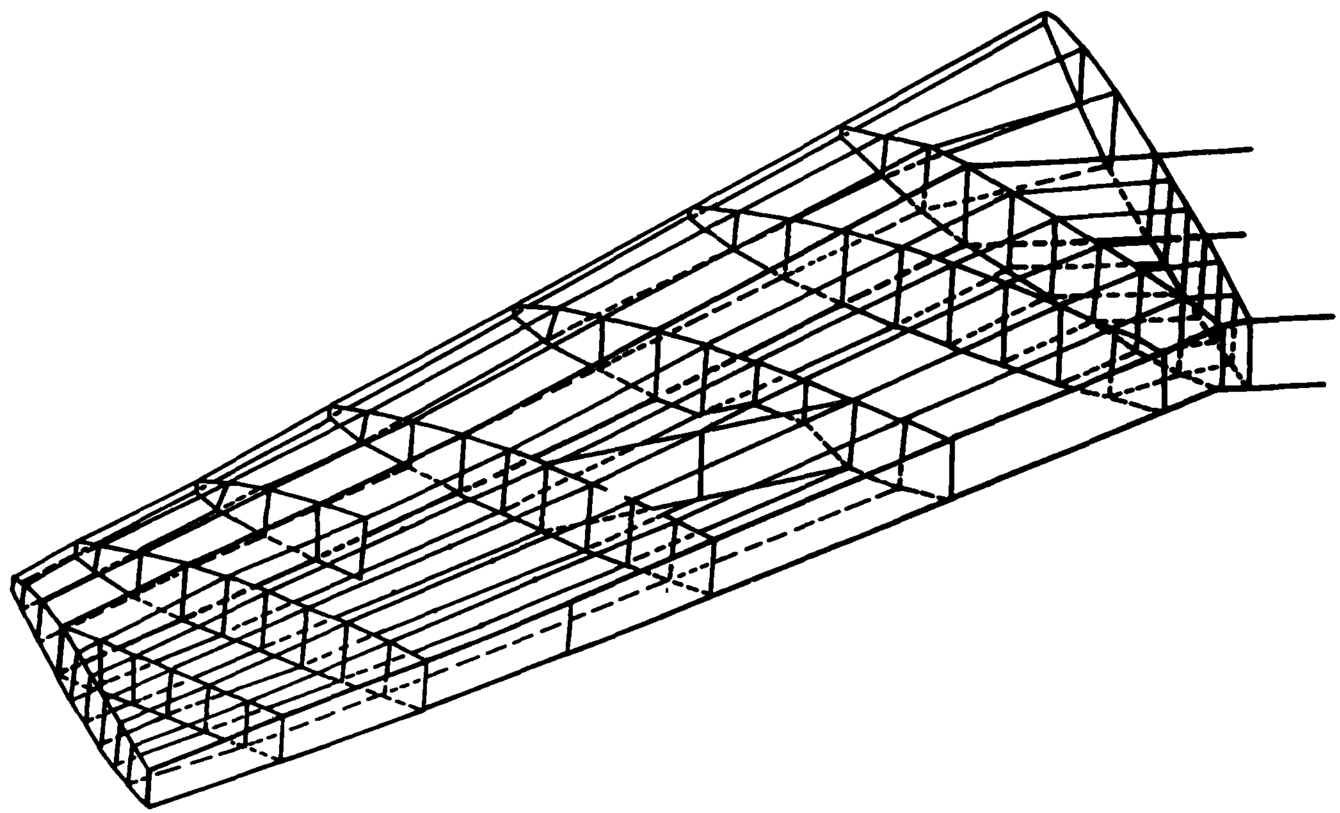


Figure 6. F-84F Finite Element Model

5.2 Model Variations

The model developed by Jordan gave him good response for conditions where bending dominated; however, it provided no torsional stiffness for the heavy structural members. To evaluate damage and load combinations producing significant torsion, model revisions included torsional stiffness for the front and rear spars.

This stiffness was provided by including rod elements along the centerlines of the spars. These elements had no axial load capacity but did provide torsional resistance. Multipoint constraint equations determined the rotation of each end of a torsion rod by using the lateral displacements of the nodes immediately above and below it. Figure 7 illustrates that the rotation, β, of the end of the centerline rod was

$$\beta = \frac{1}{h}\,(y_u - y_\ell) \tag{5.1}$$

Although modeling philosophies in the previous efforts were essentially the same, Heard used membrane elements for the skin while Jordan used shear panels. This study compared four modeling combinations. All four models used rods for skin stiffeners and for caps of spars and ribs. All used shear panels for spar and rib webs. The differences are presented in Table I. Appendix D is a listing of Model A and Appendix E is a listing of Model C. The additions for torsional resistance to convert Models A and C to Models B and D, respectively, are presented in Appendix F.

5.3 Modeling Initial Damage

To the extent possible, no special modeling techniques were applied to initial damage. Damaged shear panels or membranes were reduced in

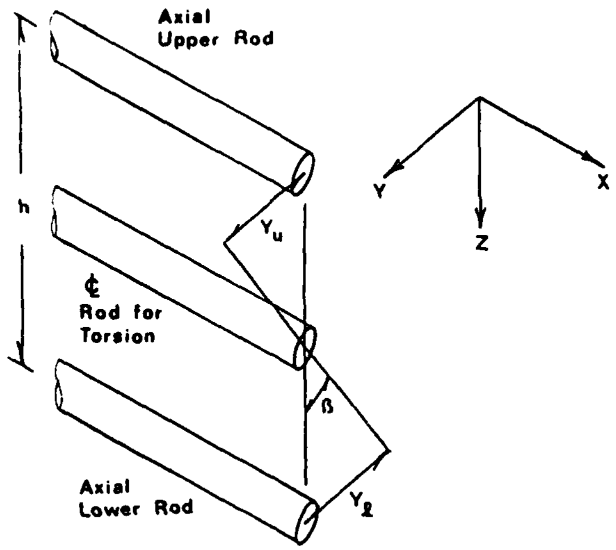


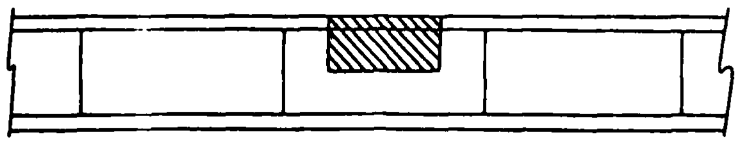
Figure 7. Rod Elements for Spar Torsional Capacity

TABLE I

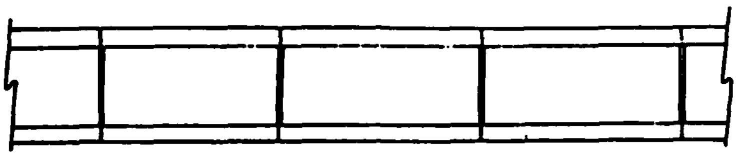
DESIGNATION OF FINITE ELEMENT MODELS

Model Designation	Skin Elements	Torsional Stiffness
A	Shear Panels	No
B	Shear Panels	Yes
C	Membranes	No
D	Membranes	Yes

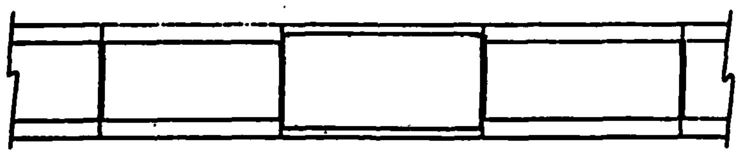
thickness or were removed when damage was severe. The rods representing damaged spars were reduced in size to maintain an equivalent moment of inertia, as presented by Jordan (32, 33). One exception to this approach was evaluated for Test 1. Damage to the front spar extended halfway into the web. Figure 8a shows a side view of the damaged front spar and Figure 8b shows modeling of the undamaged spar. The simpler modeling technique is illustrated in Figure 8c. The web element thickness was reduced to half its undamaged size. Rods representing spar caps were unmoved but reduced in size to represent the residual moment of inertia. Figure 8d shows the more detailed approach used by Jordan (32, 33) to model such severe damage. The two methods were compared. The specific changes made to Models A and C for each test are presented in Appendix G. The additional changes for Models B and D are included as part of Appendix F.



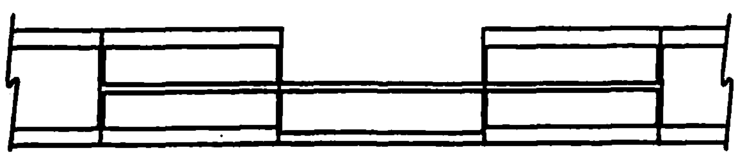
(a) Front Spar, Damaged



(b) Model, Undamaged



(c) Model, Simple Damage



(d) Model, Detailed Damage

Figure 8. Modeling Variations for Test 1 Damage

CHAPTER VI

ANALYSIS AUTOMATION

6.1 General

One shortcoming of the AFATL method cited in Chapter III was the need to examine voluminous computer output. A FORTRAN IV computer code, entitled PROSCAN for Progressive Structural Collapse Analysis, was written to alleviate the problem. PROSCAN was written to apply the method in conjunction with NASTRAN (National Aeronautics and Space Administration Structural Analysis) to perform the finite element analyses. Figure 9 illustrates the analysis procedure, and Appendix H comprises a functional flow chart and a listing of the PROSCAN program.

In exchanging information between the two computer programs, disk storage was used exclusively. All NASTRAN output was stored in punched-card format in disk files. All case control and bulk data decks were also stored on disks, and all modifications made by PROSCAN to the models were directed to those storage files.

6.2 Overstressed Elements

The first requirement in applying the AFATL method to finite element results was identifying overstressed elements. Because more than one limiting stress value was permissible, some common basis for evaluating severity of stress had to be established. The criterion selected was the margin of safety defined as

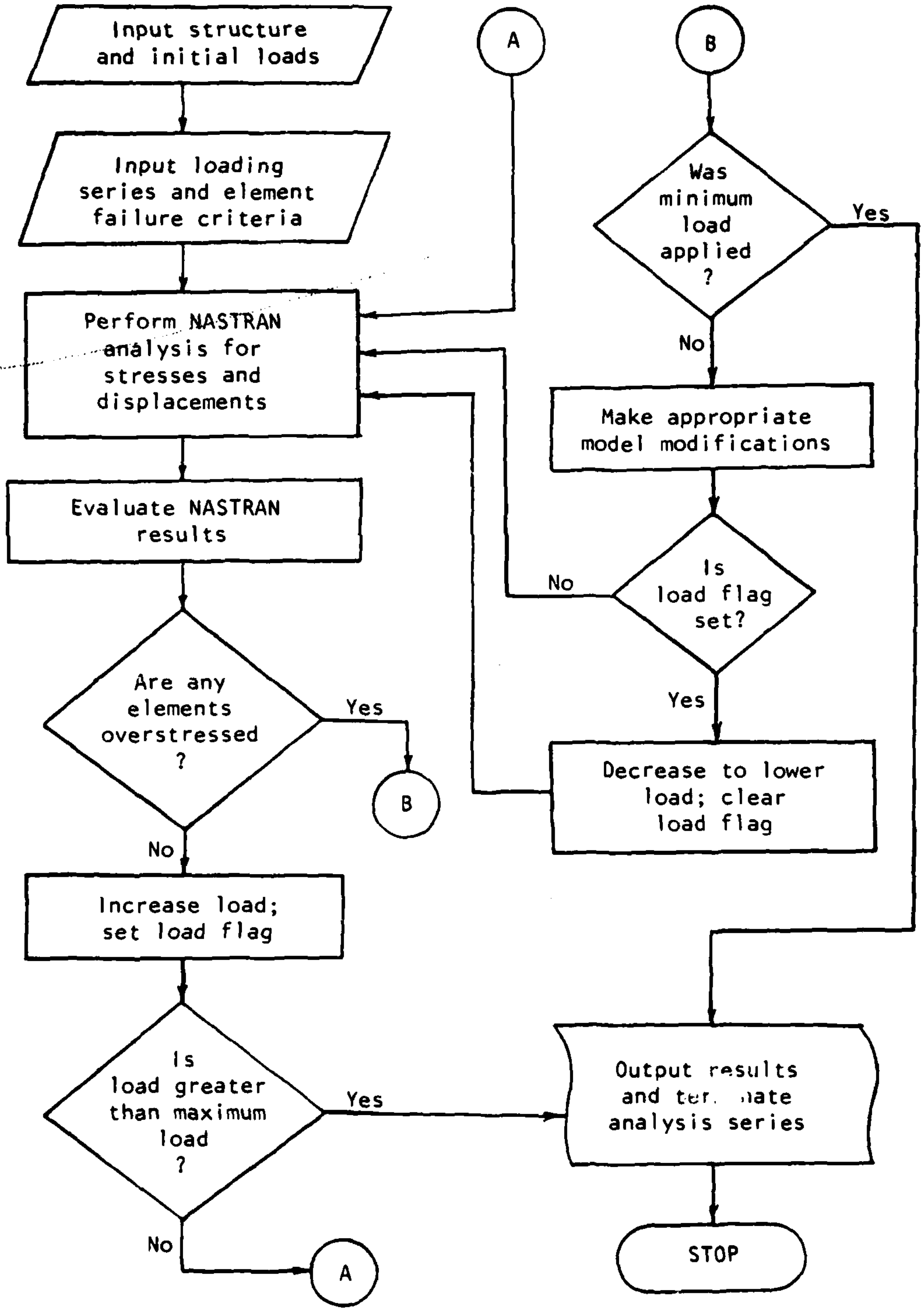


Figure 9. Iterative Analysis Procedure

$$M.S. = \frac{\text{allowable stress}}{\text{actual stress}} - 1.0 \quad (6.1)$$

Several elements within NASTRAN, rods and shear panels included, return an element margin of safety as part of the solution. For those elements which do not provide a margin of safety, PROSCAN calculated one. Element principal and maximum shear stresses were compared to analyst-provided limiting stresses for tension, compression, and shear. A margin of safety was calculated for each type of stress and the algebraically smallest value was selected as the element margin of safety. PROSCAN then identified any element with a negative margin of safety as an overstressed element.

6.3 Failed Elements

PROSCAN applied the next step of the AFATL method, grouping of overstressed elements, by node matching. The node numbers of each overstressed element were compared to those of every other overstressed element. PROSCAN designated any continuous linkage of those elements as a group, then selected the most severely stressed element from the group.

The element margin of safety again was the basis for decisions. PROSCAN selected the element of the group with the most negative margin of safety. That element became a failed element. The process of grouping and failing elements continued until all overstressed elements were considered.

PROSCAN did not actually remove a failed element from the model. Instead, PROSCAN assigned property values to the element which effectively eliminated its contribution to the structure. The failed areas and moduli of elasticity and shear were orders of magnitude below nominal values for unfailed elements.

6.4 Propagation of Damage

The failing of an element represented propagation of the damage, and as a consequence, the borders of the damage expanded. Additional elements had to be identified as bordering the new damage so they could be assigned reduced limiting stresses. Again a node matching scheme was employed. Each element which had at least one node in common with a newly failed element was examined. If it had not already failed itself or had not already bordered damage, lower limiting stresses replaced those previously used. The lowering of limiting stresses accounted for the possible presence of crack tip stress concentrations as introduced in section 2.5.

6.5 Adjustment of Load

PROSCAN had the capability of applying a new load to the model with each iteration. That capability was used in this study as explained below.

If no element failed on a particular iteration, the load was increased for the next NASTRAN analysis. This would occur until the structure sustained some maximum user-specified load without further element failure. Conversely, if an element failed on a particular iteration, PROSCAN reduced the load for the next NASTRAN analysis. The purpose was to determine the structure's ability to carry a lesser load after further weakening by the failed element. Reducing the load every time an element failed continued until the structure could not sustain a minimum load without further failure.

The analyst provided a sequence of loads to be applied, from minimum to maximum, as part of the PROSCAN input data. PROSCAN then made the

appropriate changes to the NASTRAN case control deck to reflect the structure's performance on the previous iteration. In addition to changing the load identification number, PROSCAN could assign new single point and multipoint constraint sets and identify new labels to correspond to each new load.

PROSCAN automated the entire application of the AFATL method. This began with initial viewing of NASTRAN output and finished by establishing new files containing modified case control and bulk data decks.

CHAPTER VII

DETERMINATION OF LIMITING STRESSES

7.1 Need for Limiting Stresses

Repeated reference has been made to limiting stresses. It is appropriate to address in more detail the specifics of allowable stress levels. Heard (1) used two limiting stress criteria: ultimate strength for elements away from damage, and yield strength for elements bordering damage. This study attempted to define more precisely the levels of stress which should cause failure in the model.

Ultimate strength remained the basic criterion for defining failure; but most elements, even those away from damage, were assigned limiting stresses lower than ultimate strength. Consider that a relatively large element returned a computed stress representative of a large structural region. This representative stress was unavoidably lower than the high stress within the region which would cause failure in the actual member. It was necessary then to estimate the effects of the representative stresses by using some value of limiting stress lower than ultimate strength.

Appropriate limiting stresses also estimated the nonlinear behavior experienced through the buckling of skin panels. Since the finite element analyses assumed linearly elastic behavior, the ability to compensate for skin panel buckling was incorporated to enhance results. PROSCAN had the ability to incorporate both the low stresses causing buckling and the reduced stiffnesses subsequent to buckling.

7.2 Limiting Stresses for Rod Elements

Spar and rib sections were each represented by three elements. A shear panel represented the web. One rod element represented the upper spar cap and another rod represented the lower spar cap. The rods were sized and spaced to maintain the moment of inertia about the section's neutral axis and to return outer fiber stresses.

The stress value obtained for rod elements was the average of the stresses at each end of the rod. Because rod elements in the spars were relatively long, the average stress could be substantially less than the maximum stress. A procedure to obtain limiting stresses for a similarly modeled doubly symmetric cantilevered beam served as a foundation for developing limiting stresses for the wing model. Figure 10 shows such a beam with top rod elements numbered and top nodes lettered.

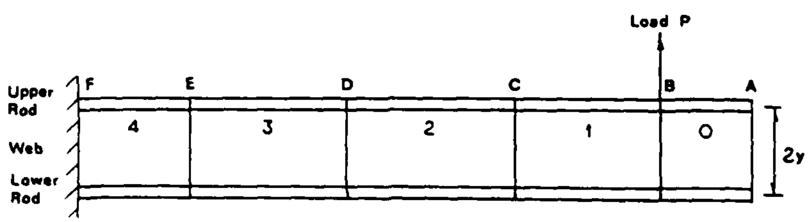


Figure 10. Cantilevered Beam Model

Using rod 3 for illustration, the maximum stress from the applied load occurred at node E, but the stress obtained was the average of

stresses at nodes D and E. Designating L_j as the length of any member j, the average stress in rod 3 was

$$\sigma_{avg} = \frac{P(L_1 + L_2 + \frac{1}{2} L_3)y}{I} \qquad (7.1)$$

and the stress at node E was

$$\sigma_{max} = \frac{P(L_1 + L_2 + L_3)y}{I} \qquad (7.2)$$

where I was the section moment of inertia. Designating a limiting stress factor, F_i, as the ratio of σ_{avg} to σ_{max},

$$F_3 = \frac{L_1 + L_2 + \frac{1}{2} L_3}{L_1 + L_2 + L_3} \qquad (7.3)$$

In general terms,

$$F_i = \frac{\frac{1}{2} L_i + \sum_{j=1}^{i-1} L_j}{\sum_{j=1}^{i} L_j} \qquad (7.4)$$

for the single point load shown. The appropriate limiting stress, σ_{L_i}, was

$$\sigma_{L_i} = F_i \, \sigma_{ult_i} \qquad (7.5)$$

where σ_{ult_i} was the ultimate strength for the member i.

To extend this approach for calculating stress factors to the finite element model of the wing, the wing itself was idealized as a straight cantilevered beam. The front spar dimensions were used for section lengths as shown in Figure 11. Upper surface element numbers are below each rod and corresponding node numbers are above each node.

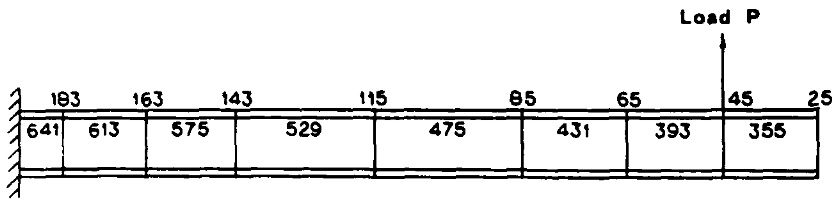


Figure 11. Cantilevered Front Spar Idealization

Factors to reduce material ultimate strength for elements inboard of the load were calculated as shown in the previous example. Elements between the load and the wing tip used the same factor as the elements immediately inboard of the load. Table II shows the limiting stress factors for the front spar rods on the upper wing surface.

TABLE II

LIMITING STRESS FACTORS FOR ROD ELEMENTS

Rod No.:	641	613	575	529	475	431	393	355
F_i:	0.950	0.937	0.921	0.855	0.788	0.735	0.500	0.500

Each rod representing a skin stiffener was approximately parallel to the spars and was assigned the same factor as its corresponding spar element. Each rib was approximately perpendicular to the spars. Each rod in a rib was assigned the factor of the spar rod immediately inboard of the spar-rib intersection.

A single concentrated load was used for analysis to correspond to the actual loading applied in the laboratory test program. However, an aerodynamic load could be represented by any approximation acceptable to the analyst. Although the mathematical expression for F_i would be more complex, the same approach to factoring for limiting stresses in rod elements could be applied.

7.3 Limiting Stresses for Web Elements

Shear panel elements represented the webs of spars and ribs. The limiting stress for shear was determined by comparing the average shearing stress in the web to the maximum shearing stress in the web. If V were designated as the shearing force in the cantilevered beam discussed in the previous section, the web element yielded a shearing stress of

$$\tau_{avg} = \frac{V}{2yt} \tag{7.6}$$

where t was the web thickness. The maximum shearing stress in the section was

$$\tau_{max} = \frac{VQ}{It} \tag{7.7}$$

The limiting stress factor, F, was the value of τ_{avg} divided by τ_{max}, so the limiting shearing stress, τ_L, was

$$\tau_L = F\,\tau_{ult}\ . \tag{7.8}$$

Calculations for typical spar cross sections showed F = 0.85 to be a representative value. This value was applied to all spar and rib web elements.

Proportions of spar and rib sections indicated web crippling was unlikely; therefore, no reductions in limiting stresses were developed for buckling of undamaged web members. If initial damage to the structure introduced a potential for buckling, residual member proportions dictated the appropriate reductions.

7.4 Limiting Stresses for Skin Elements

Skin panels, unlike spar and rib webs, were susceptible to buckling. Additionally, the skin could tear along rivet lines or rivets themselves could fail. Whether a panel buckled in shear or in compression, or failed along a rivet line, the result was a reduction in stiffness of the panel. Because of the similar change in behavior, panels were divided into either pre-buckling or post-buckling categories even though rivet line failure was not a buckling phenomenon.

Each skin panel on the wing had slightly different geometric properties which gave each slightly different pre- and post-buckling characteristics. Panel 106, forward of the front spar on the lower wing surface, was typical of most skin panels and was used to determine approximate values for all panels. Figure 12 shows its location in the model. The assembly used for calculations included panel 106, a stiffener attached to each long side, and a rib attached to each short side. Averaging the lengths of the two long sides and the two short sides gave a rectangular shape for calculations.

To determine pre-buckling limits, compression perpendicular to the long sides, compression perpendicular to the short sides, and a corner force producing shear were all evaluated separately. Calculations were determined according to Peery (34, Chapters 14 and 15). The average

stress causing buckling in each case was divided by the material ultimate strength to determine the limiting stress factors, F. For the two compression conditions, the more conservative value was used.

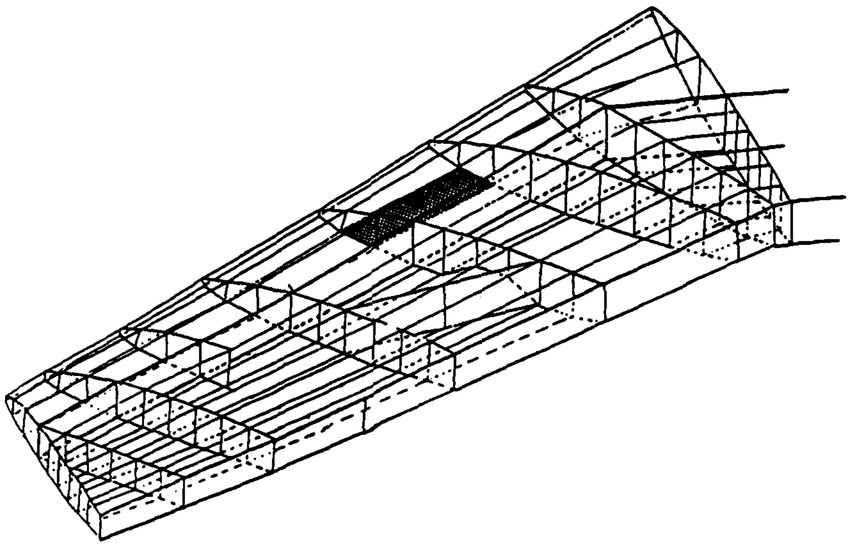


Figure 12. Typical Panel for Buckling Limits

Limits for tension were obtained by calculating rivet and skin strengths along a conservative rivet line. Limiting loads, determined according to Peery (34, Chapter 12) and Bruhn (35, Chapter D1), were divided by the ultimate load, the load causing an average stress in the panel equal to the ultimate strength. The result was the limiting stress factor. Skin failure was compared to rivet failure, and the more conservative value was used.

For post-buckling behavior, the limiting stresses were returned to ultimate strength, but the elastic and shear moduli were reduced to

account for the reduction in stiffness following buckling. For compression buckling, bilinear behavior was assumed. The load versus displacement curve of Figure 13a assumed linear behavior prior to buckling, then linear behavior from buckling to an ultimate strength failure. The slope of the pre-buckling portion of the curve, S_1, was divided into a secant slope, S_2, from the origin to failure. The result was a reduction factor, M, for the elastic modulus. The same process applied to Figure 13b produced a reduction factor for the modulus of shear. Table III summarizes the results for skin buckling.

TABLE III

LIMITING FACTORS FOR SKIN ELEMENTS

Behavior	Stress Factor F	Modulus Factor M
Compression, Pre-buckling	0.17	1.00
Shear, Pre-buckling	0.32	1.00
Tension, Pre-buckling	0.55	1.00
Compression, Post-buckling	1.00	0.76
Shear, Post-buckling	1.00	0.53
Tension, Post-buckling	1.00	0.76

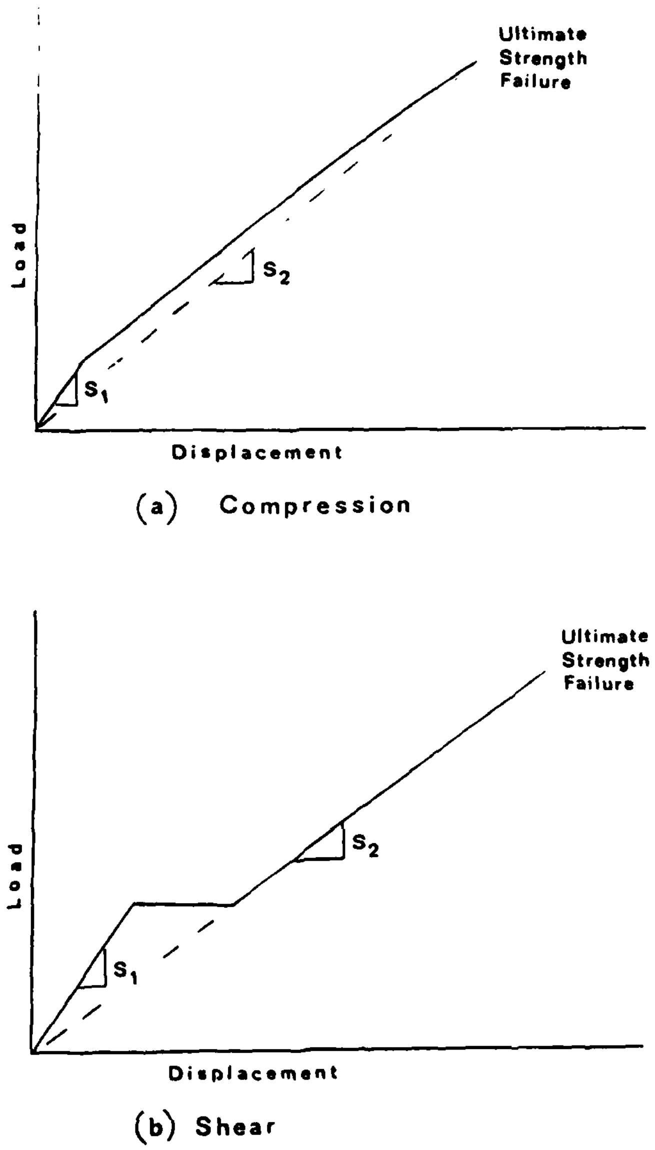


Figure 13. Load-Displacement Curves for Panel Buckling

Although the assumption of linear behavior from buckling to ultimate failure was not correct, it was a conservative representation of the rather brittle material behavior observed in the laboratory. The result economically approximated the loss in stiffness suffered by the structure from skin buckling and rivet line failure.

7.5 Damage Propagation

No attempt was made to model ragged edges around initial damage nor to reduce element size in areas of propagating cracks. The large elements then tended to mask the stress concentrations around cracks and produced a model significantly more resistant to progressive collapse than the structure being represented.

Conventionally, the nominal stress in a cracked member would have been multiplied by a stress concentration factor, K. Its value would have been larger than 1.0 and based upon crack length and crack tip severity. The increased value for stress at the crack tip would then have been compared to an allowable stress for the member. PROSCAN used an inverse approach. Rather than increase the nominal stress returned by an element, the allowable stress was decreased by a factor F, where F essentially was the inverse of K. This further reduction of limiting stresses compensated for the absence of increased modeling detail around damage.

Any cracks occurring were assumed to originate at the initial damage or in subsequently failed elements. The further reductions in limiting stresses applied therefore only to unfailed elements bordering either initial damage or failed elements.

Separate reduction factors were determined for tension and for shear. Because cracks were assumed not to propagate in compression, no further

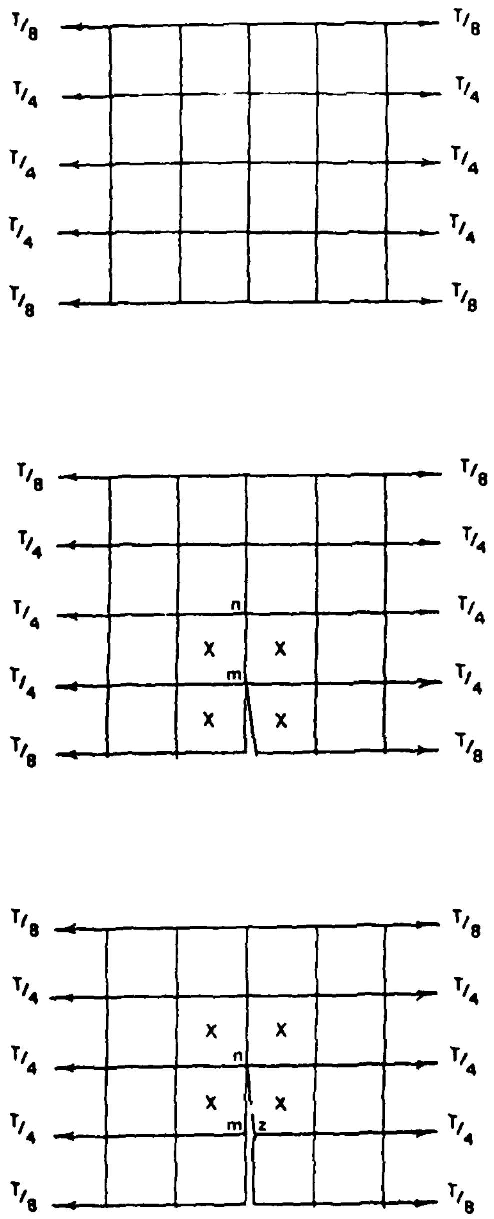
reduction applied to limiting compressive stresses. This portion of the investigation was patterned after similar crack propagation studies by Sih and Hartranft (28).

Two square plate models, one loaded in tension and the other in shear, provided information for reduction factors. Model detail ranged from two elements along a side to thirty-two elements along a side.

A crack initiated at the center of one edge propagated through the plate during sequential analyses. Loads remained constant through all iterations. Crack propagation was represented by creating a new node beside the tip of the crack, thus extending the crack to the next node. Figure 14 illustrates the procedure, exaggerated in scale, on a model using four elements per side. Figure 14b shows node m at the tip of the crack. The creation of node z extended the crack tip to node n in Figure 14c.

Figure 14b shows the plate cracked one-quarter of the way through its width. Stresses in the four elements connected to the node at the crack tip, those indicated by X's, were averaged and then divided into the average stress in the uncracked plate. The result was the limiting stress factor for the plate cracked through one-quarter of its width. The same procedure applied to the plate in Figure 14c produced the factor for the plate cracked halfway through its width. Figure 15 shows variation of the factor as a function of model detail and crack length. F_T represents tension loading and F_S represents shear loading.

All curves in Figure 15 appeared to approach zero slope as element size reduced. The values of F_T and F_S selected for this study were for a plate cracked one-eighth of the way through its width in a model with 32 elements along a side. For most components of the F-84F wing, this

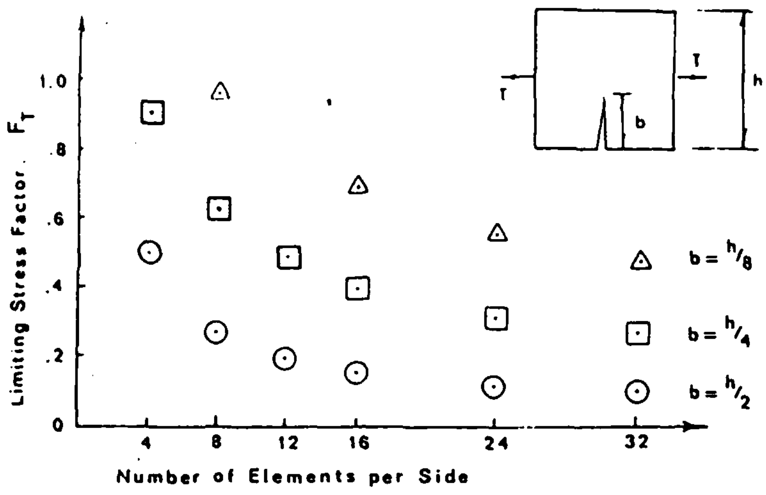


(a) Uncracked

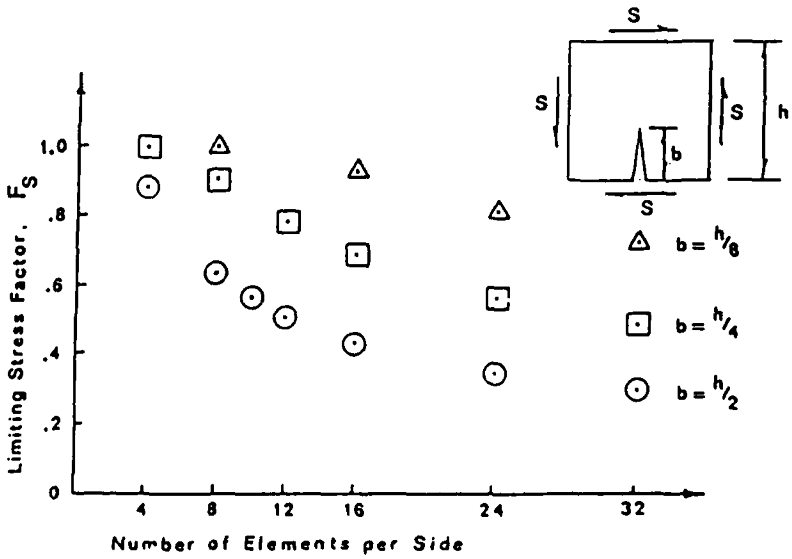
(b) Cracked Through 1/4 of Width

(c) Cracked Through 1/2 of Width

Figure 14. Crack Investigation Models



(a) Tension



(b) Shear

Figure 15. Propagation Stress Factor Curves

represented a crack less than one inch in length in the longer side of the component. The corresponding stress concentration factor was $K = 2.1$. For skin panel 106, it represented a crack 0.725 inches long with a crack tip radius of 0.30 inches calculated according to Seely and Smith (36, Chapter 12). Thus the assumed crack around damage was relatively mild and was therefore conservative.

New limiting stresses for an element bordering damage were the product of the appropriate factor, F_T or F_S or $F_C = 1.0$ for compression, and the element's previous limiting stresses. Limiting stress factors were, in this manner, cumulative. The exception was unbuckled skin panels. Their limiting stresses were not reduced to reflect cracks until after buckling stresses were exceeded.

CHAPTER VIII

COMPARISON OF RESULTS

8.1 General

Damage and load conditions for Tests 2C and 3B were analyzed using all four models for each test. Measured rotations of wing spar roots from laboratory data were enforced in the analyses. Examination of those analyses showed the addition of torsional rod elements to the spars made little difference in results. The performance of Model B was very similar to that of Model A, and the results from Model D were almost identical to those from Model C. Apparent reasons for the similarities are presented in the next section.

Further examination of the analytical results revealed unexpected stress distributions in and near the wing spar roots. The enforced rotations of wing spar roots, although developed from experimental measurements, did not produce purely rigid body motions for reasons explained in section 8.6. Consequently, the original analytical representations did not match closely enough the laboratory conditions of the experimental test program.

A second set of analyses was performed using zero support rotations for stress determination and enforced rotations for checking displacements. Tests 2C and 3B were analyzed using Models A and C for each test. Model C described the collapse phenomenon more closely than Model A as explained in section 8.4. Therefore, Model C was next compared to Model

D, the same model with the addition of torsional rod elements. The lack of significant different between Models C and D confirmed the minimal influence of the torsional rod elements. Model B, therefore, was not analyzed further because it would produce essentially the same results as Model A. Even though torsional rod elements were not significantly affecting results, Model D was selected for the comparison of initial damage modeling since its torsional capability could provide greater latitude for an analyst to adjust model stiffness.

Model D was used to evaluate the two approaches to modeling damage for Test 1 described in section 5.3. The simpler method of modeling portrayed more accurately the pattern of failure as explained in section 8.5. The simpler method of modeling the damage was then applied to Model A for a final analysis of Test 1.

8.2 Comparison of Failure Loads

A close correlation of analytically predicted failure loads with experimentally measured failure loads would be a desirable result of evaluating the AFATL method. Table IV summarizes the failure load results. The models ranged from 5 percent to 85 percent stronger than the actual structure. Note that for Test 2 no experimental failure load was determined; therefore, conclusions about Test 2 are judgmental.

Model A gave the closest approximation for Test 3 and may have given a close approximation fo.· Test 2. However, for reasons discussed in section 8.4, Model A was not considered the best model. Model D was more conservative than Model A in estimating wing strength. Although Model D's predicted strength for Test 2 was clearly less conservative than for Test 3, the results may have been acceptabiy consistent. Both approaches

for modeling Test 1 damage gave excessive predicted strengths; however, section 8.5 discusses how those figures might be improved.

TABLE IV

SUMMARY OF FAILURE LOADS

Test	Failure Loads (kips)			
	Laboratory	Model A	Model C	Model D
1	12.0	22	---	22
2	15.0*	18	20	20
3	12.4	13	19	19

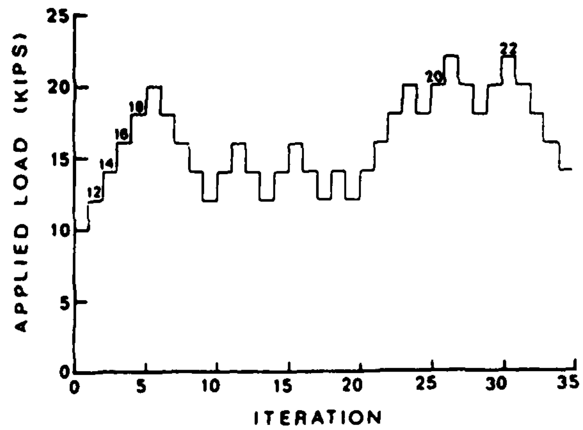
*Largest load applied; no failure load determined.

Models C and D showed no differences in failure loads and very little difference in the sequences of element failure. There are two apparent reasons for the similarity. The first is that the torsional capacities of the spars were probably underestimated when the torsional rod elements were sized. Second, bending was the dominant behavior of the F-84F wing even under extreme conditions such as those of Test 2.

8.3 Load-Iteration History

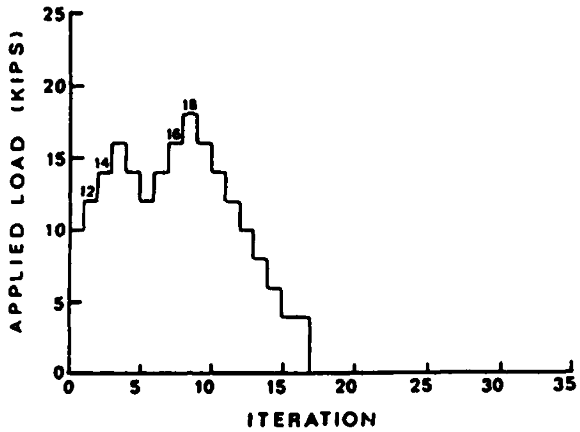
The AFATL method, as applied by PROSCAN, caused loads to vary from iteration to iteration. Figure 16 depicts the variation of load with respect to iteration for the first 35 cycles for Models A and D. The analytical data for any given load level were taken from the last cycle in which that load was applied before the model experienced a higher load. For

(a) Test 1. Model D (with torsional stiffness rods). Simple

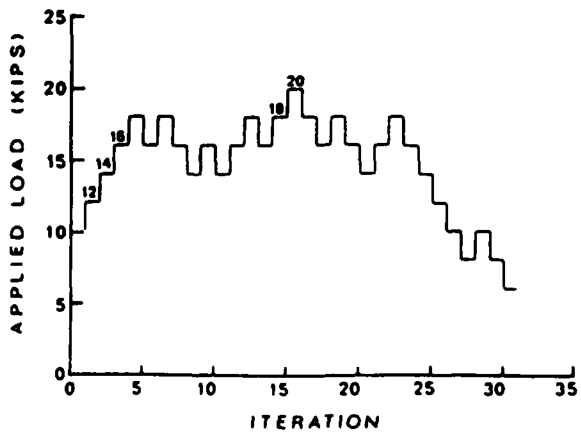


(b) Test 1. Model D (with torsional stiffness rods). Detailed

Figure 16. Load-Iteration Histories

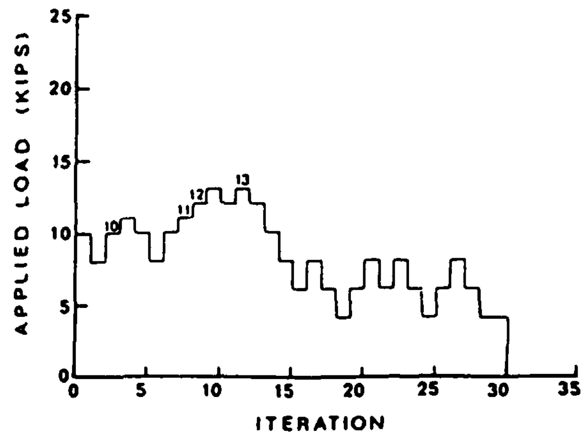


(c) Test 2C, Model A (without torsional stiffness rods)

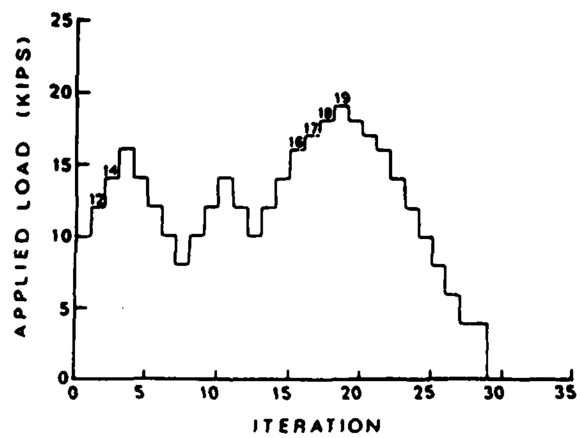


(d) Test 2C, Model D (with torsional stiffness rods)

Figure 16. (Continued)



(e) Test 3B. Model A (without torsional stiffness rods)



(f) Test 3B. Model D (with torsional stiffness rods)

Figure 16. (Continued)

example, the analytical data for the Model A analysis of Test 2C at 16 kips applied load came from iteration No. 8. As shown in Figure 16c, that was not the first application of a 16-kip load, but it was the last iteration before a higher load, 18 kips, was applied.

That procedure for selecting which iterations to use for data comparison occasionally led to gaps of several iterations between successive data-producing loads. Again as an example, Figure 16f shows 13 iterations elapsed between the 14-kip and 16-kip loads for the Model D analysis of Test 3B. During those cycles, six elements failed. This characteristic of the procedure accounted for the occasional sharp discontinuities in the plots of data.

Figure 16 also emphasizes the need for caution in setting the minimum load to be investigated. PROSCAN permitted the load to drop considerably during a series of element failures, then again rise to a high level. Figure 16a shows how the load dropped from 22 kips down to 12 kips before again climbing back up to 22 kips. Making the minimum allowable load too large could result in a premature indication of structural failure. It could occur during such a series of element failures when, in fact, the structure still possessed the capacity for loads well above the minimum level.

8.4 Internal Load Paths

The most demanding test of the models was how realistically they transferred the loads internally through the wing structure and into the supports. Figure 26 (Appendix I) compares the vertical support reactions for experimental and analytical results. Figures 27 through 29 (also

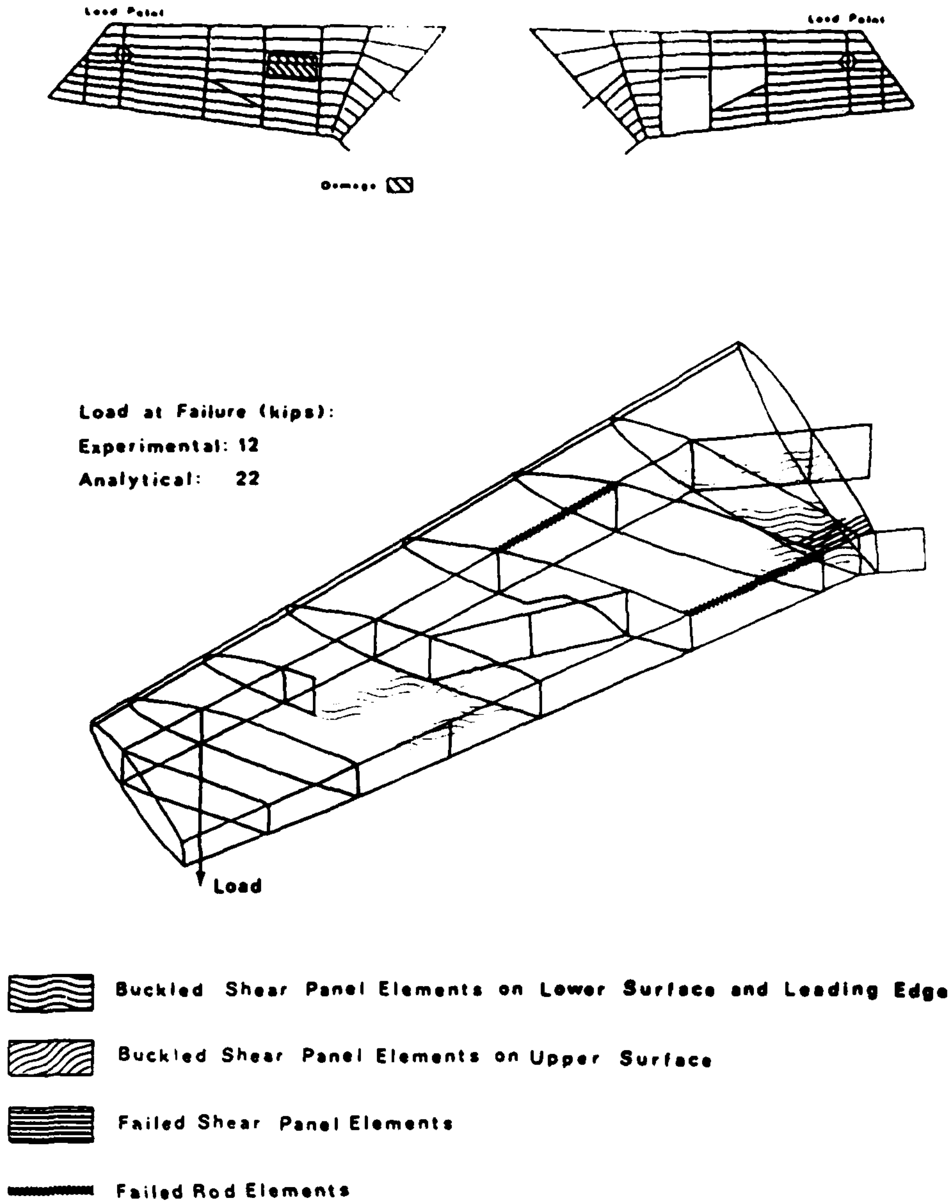
Appendix I) compare variations of strain at representative points on the wing with respect to applied load.

Examination of Figure 26 through 29 showed that neither Model A nor Model D transferred the load from the loaded spar to the unloaded spar as quickly as the actual wing did. Additionally, neither model transferred as much of the load from spar to spar as the wing did.

The most important indication for this study of how realistically the models transferred the loads internally came from Figures 17 through 19. They depict the buckled and failed elements in Models A, C, and D at their respective failure loads. For Test 3B, Figure 19, Model A did not indicate the nature of the failure as observed in the experimental test program; however, Models C and D did match closely the laboratory observations. For Test 2C, Figure 18, no failure occurred in the experimental program, but Models C and D predicted a plausible failure. Model A, however, predicted failure of the front spar at one of its strongest sections. For Test 1, Figure 17, Model D matched the laboratory failure pattern very closely using the simple modeling of initial damage. Model A, however, indicated failure of the undamaged rear spar. All models indicated more overstressing of skin elements near the wing spar roots than was observed on the actual wing. A complete summary of results for the first 35 iterations of the principal series is presented in Appendix J.

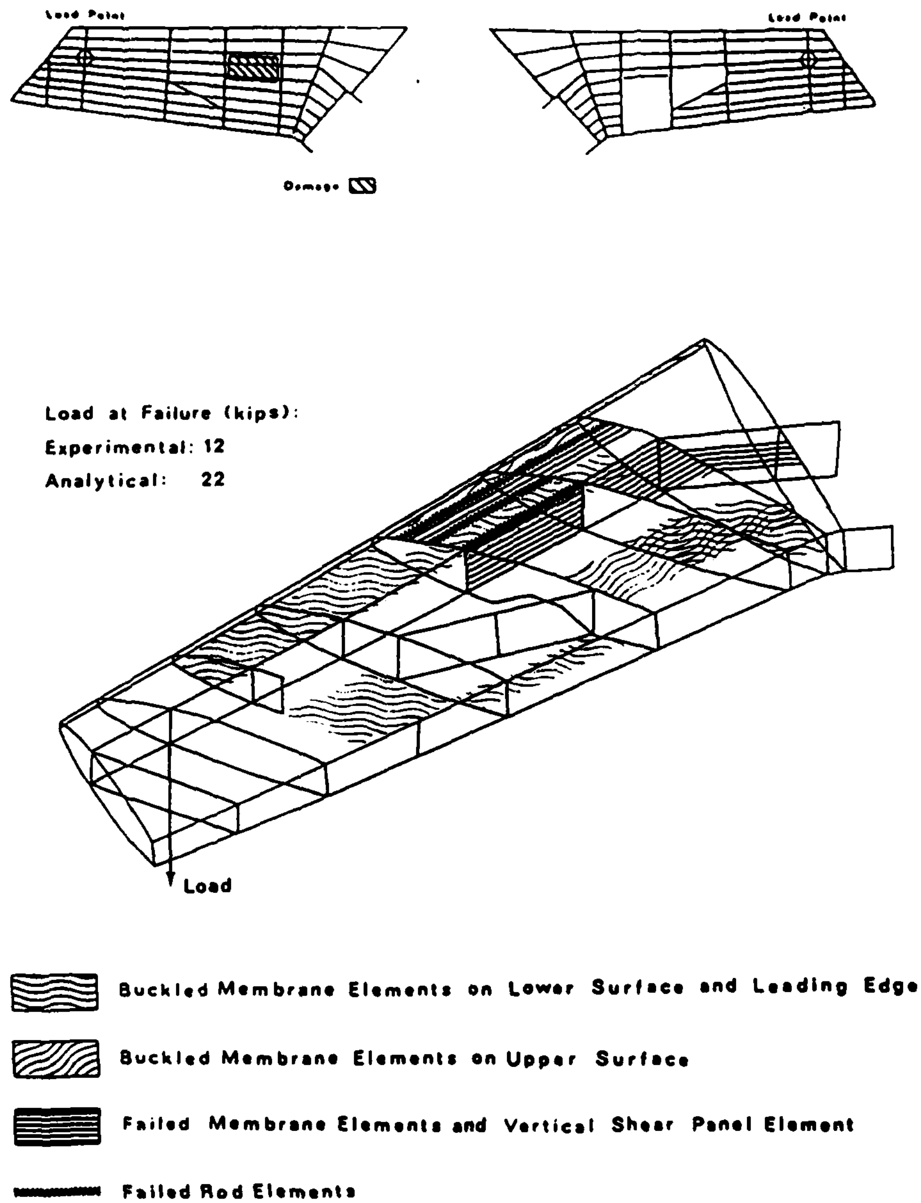
8.5 Comparison of Damage Modeling

Section 5.3 introduced two approaches for modeling Test 1 damage. Both approaches predicted the same failure load, but Figure 17 illustrates that there were significant differences in which elements failed.



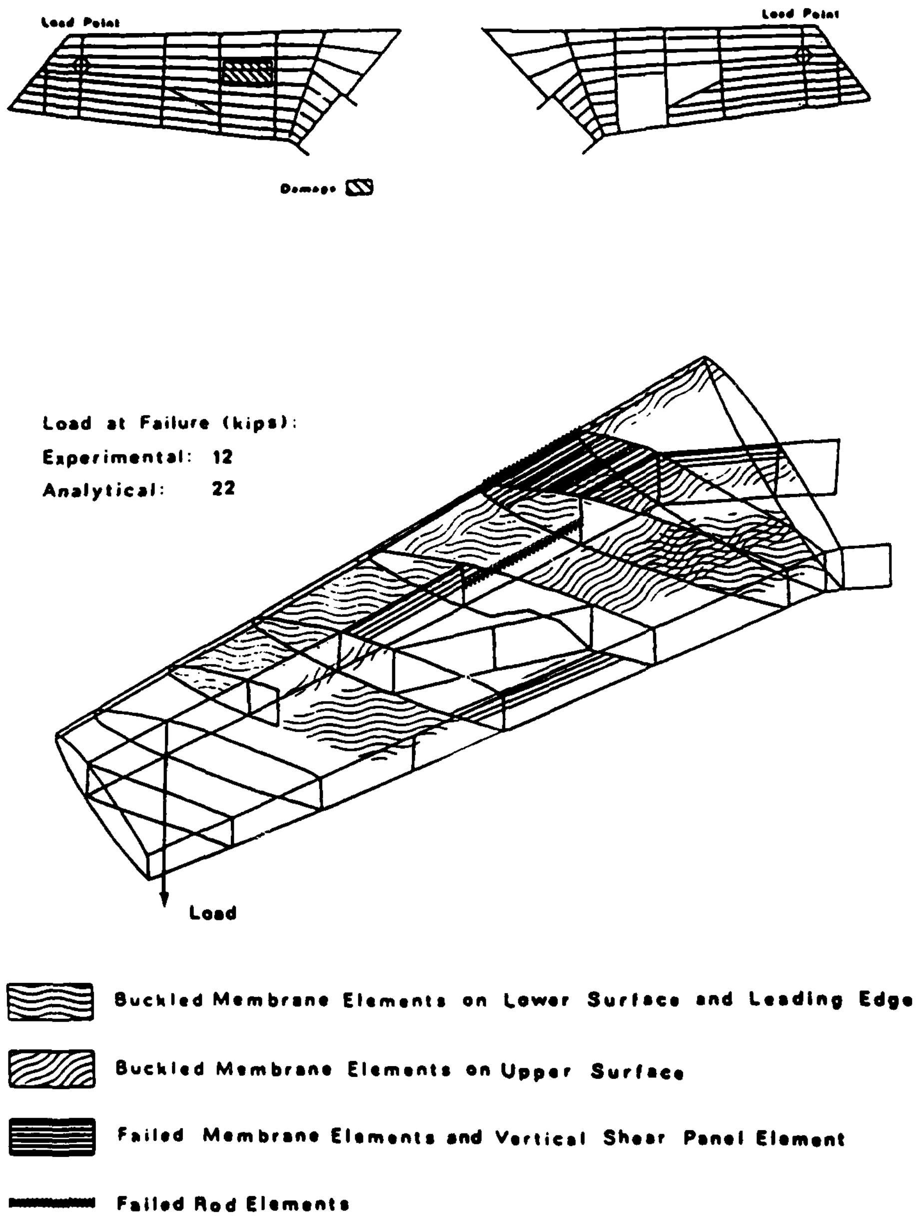
(a) Model A (without torsional stiffness rods). Simple

Figure 17. Wing Model Results at Test 1 Failure



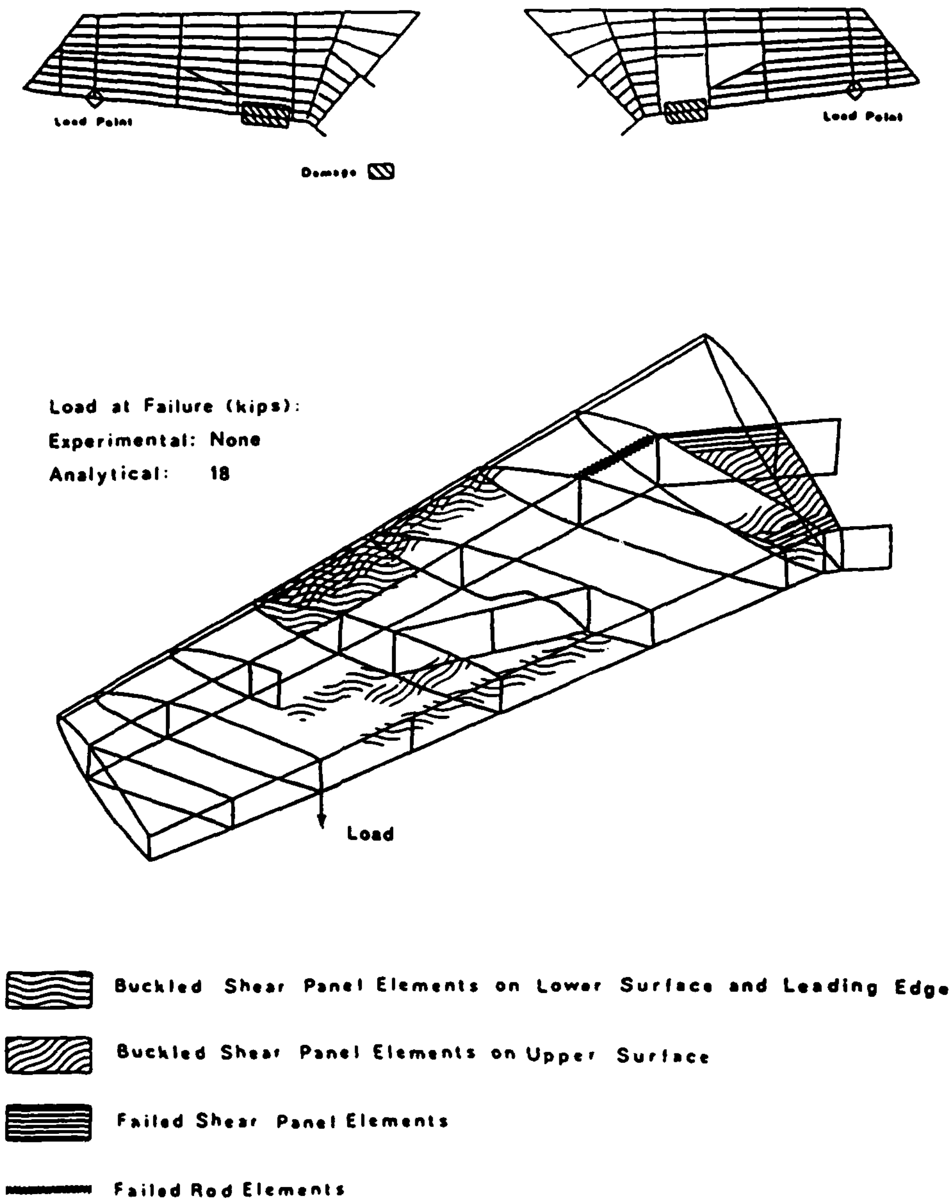
(b) Model D (with torsional stiffness rods) Simple

Figure 17. (Continued)



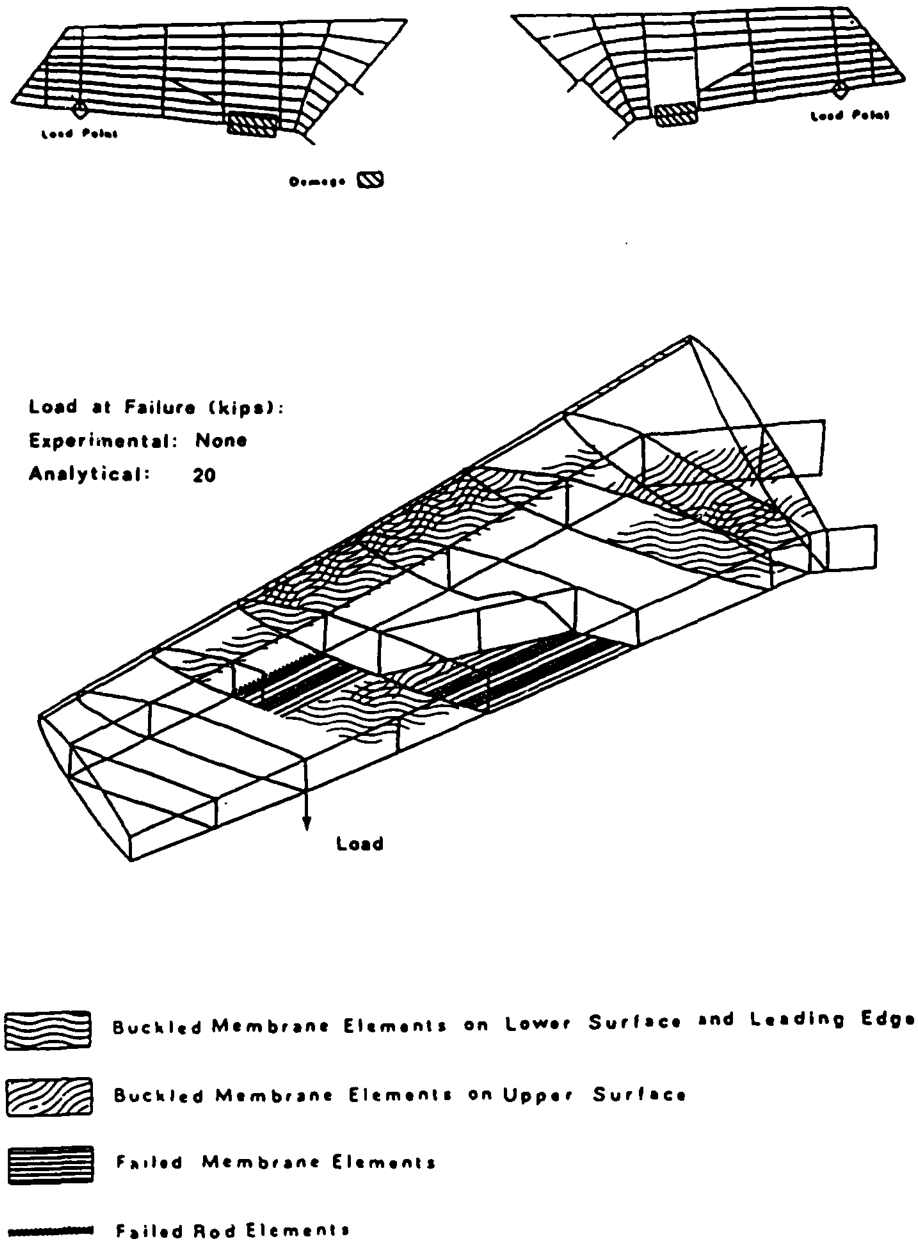
(c) Model D (with torsional stiffness rods). Detailed

Figure 17. (Continued)



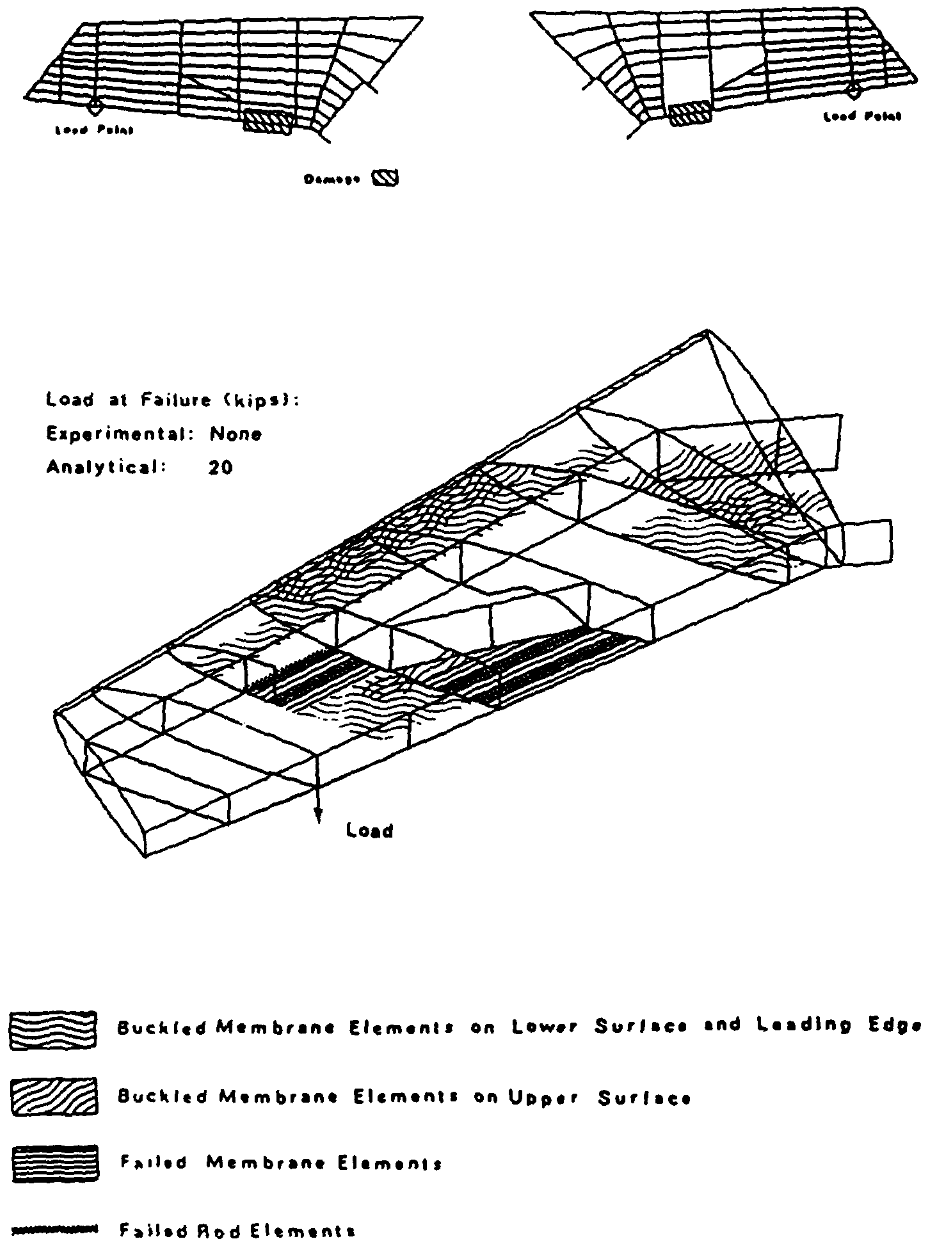
(a) Model A (without torsional stiffness rods)

Figure 18. Wing Model Results at Test 2C Failure



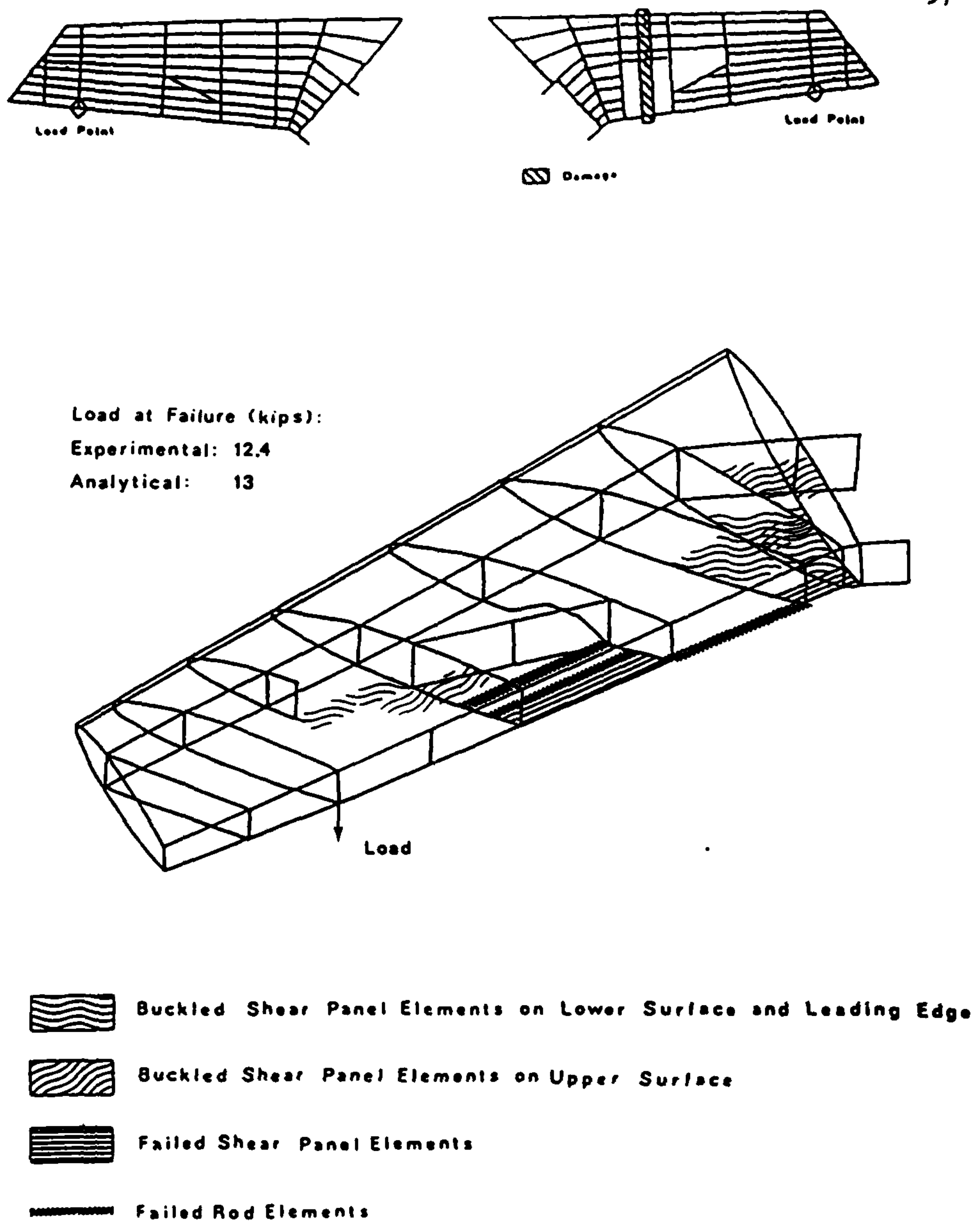
(b) Model C (without torsional stiffness rods)

Figure 18. (Continued)



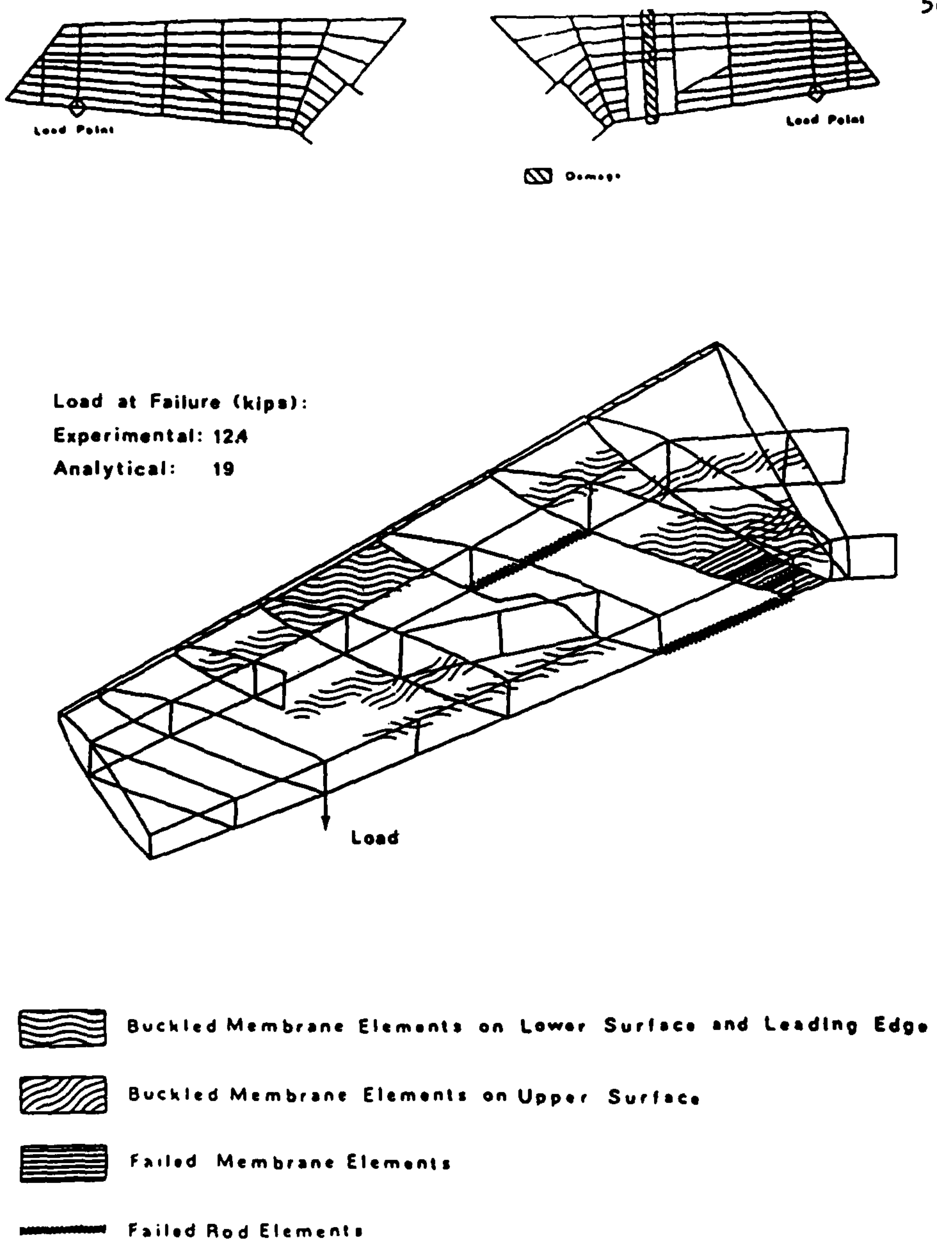
(c) Model D (with torsional stiffness rods)

Figure 18. (Continued)



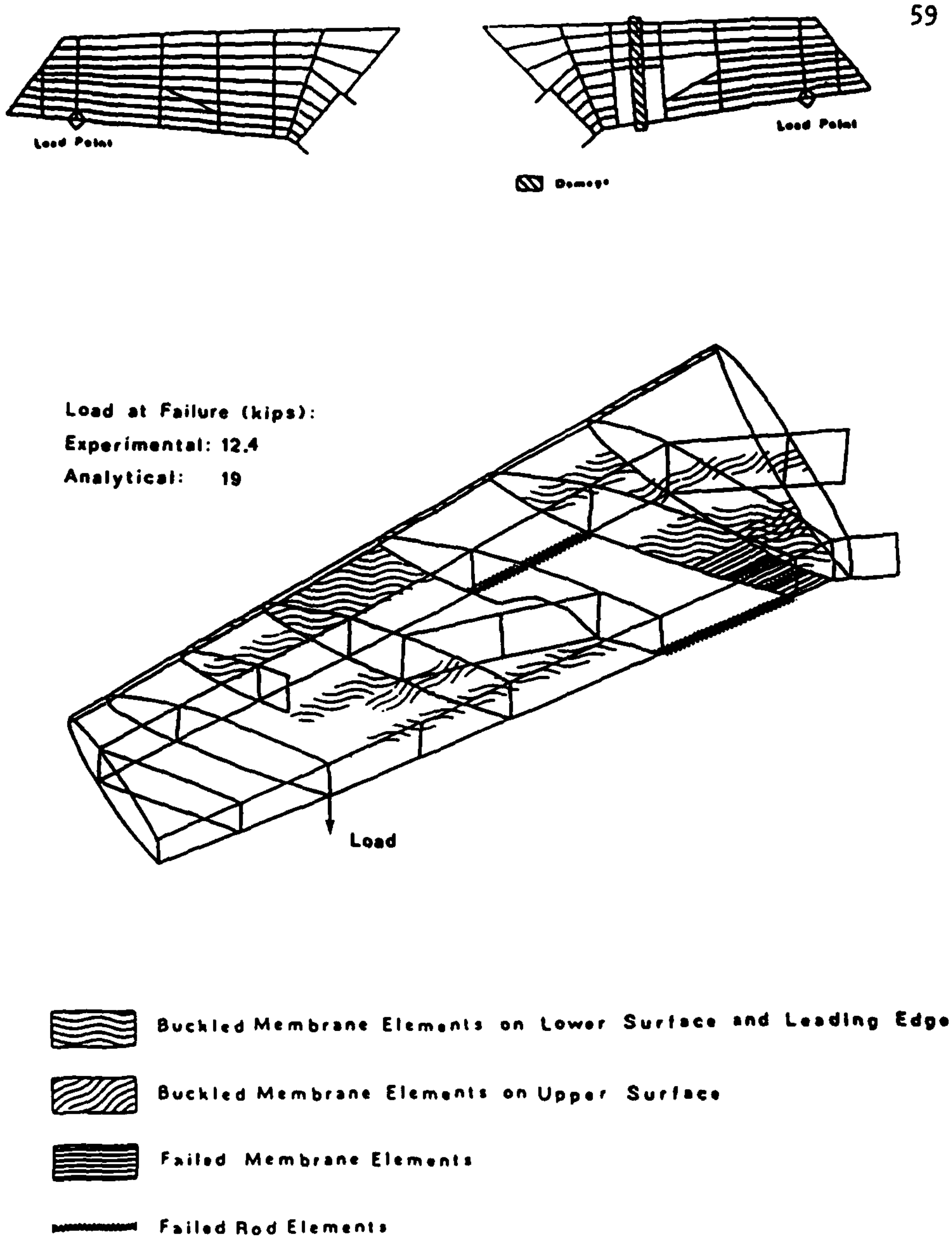
(a) Model A (without torsional stiffness rods)

Figure 19. Wing Model Results at Test 3B Failure



(b) Model C (without torsional stiffness rods)

Figure 19. (Continued)



(c) Model D (with torsional stiffness rods)

Figure 19. (Continued)

Of the two approaches using Model D, the simpler approach depicted more accurately the failure as observed in the laboratory. The simple approach applied to Model A did not produce an accurate failure pattern; however, all tests indicated that Model A was less suitable for predicting the pattern of failure.

Although the Model D results suggested a preference for the simpler technique, caution is advised before reaching a firm conclusion. In all models for all tests, the webs of spars and ribs were represented by shear panels. Consequently, the front spar in Test 1 could not fail at the damage until shear limits were exceeded. The experimental program showed the damaged front spar web in Test 1 failed in bending tension, a failure mode the shear panel could not predict. For cases of initial damage where all or most of a spar cap or rib cap would be removed, the web should probably be modeled by a membrane element. Although the membrane element would be stiffer than the shear panel, it would be directly sensitive to limiting tensile and compressive stresses as well as to shear limits. Such a recommendation applied to this study may have appreciably reduced the predicted failure load for Test 1, and it may have altered the apparent value of simple modeling over the more detailed representation.

8.6 Rotation of Wing Spar Roots

Specific values of displacement were of interest in this study as an additional means of comparing analytical results to laboratory data. To obtain more accurate displacement values from the analytical method, rotations of wing spar roots were measured in the experimental test program and enforced in the analytical models. However, for most applications of

the AFATL method, rotations at structure supports would not be known. Additionally, the precise displacements of the structure probably would be unimportant. The displaced shape of the structure, which might be used to modify loading for each iteration, was available from the analyses using zero support rotations.

The enforced rotations were derived from experimental data. In translating laboratory measurements into single point constraints for NASTRAN, an assumption was made. It was assumed that the center of rotation for each spar was the point midway between the two pins securing the spar in its support structure. In fact, any point between those two pins could have been the center of rotation, and the center could have changed as loading progressed. The assumption almost certainly contributed to the introduction of erroneous stresses into the models during the first set of analyses.

Another likely contributor to those stresses was the manner in which some of the multipoint constraint equations for the models were written. A spar root was modeled by a shear panel and two rod elements, a configuration that gave the desired resistance to bending but provided no lateral restraint. The necessary lateral restraint was provided by multipoint constraints to keep each root section in line with its adjacent spar section.

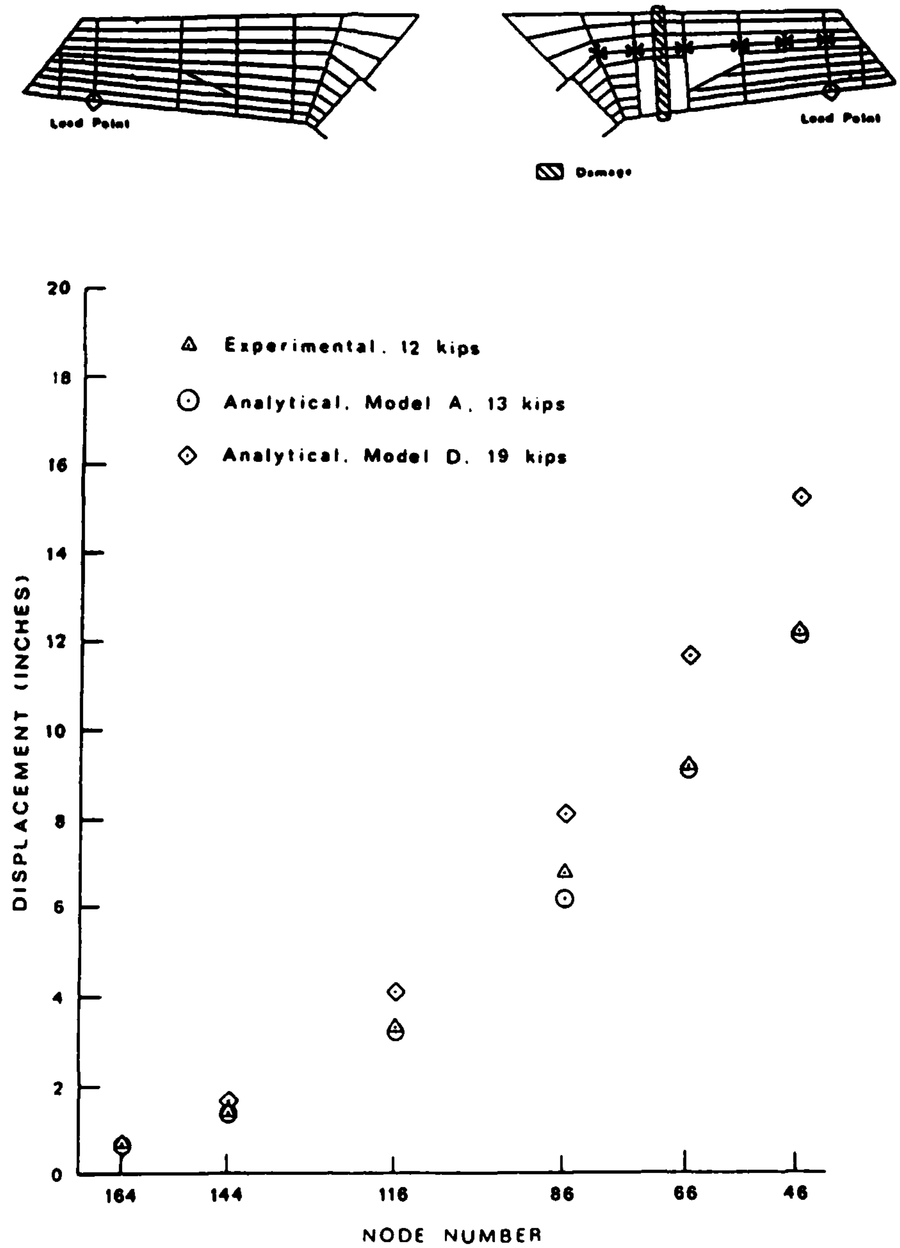
The multipoint constraint equations for the original model were formulated not in a general manner, but with an implied assumption that there was no displacement of the wing spar root nodes. Thus any attempt to enforce the measured rotations violated that assumption. The result was erroneous stresses near the base of the wing.

Of the two sources of error identified, the multipoint constraint equations could be easily corrected. The problem of precisely measuring wing spar root rotations cannot be solved without sophisticated measuring equipment. The benefits gained from precise measurements, however, would not begin to justify the added expense for normal applications of the method.

8.7 Deflections

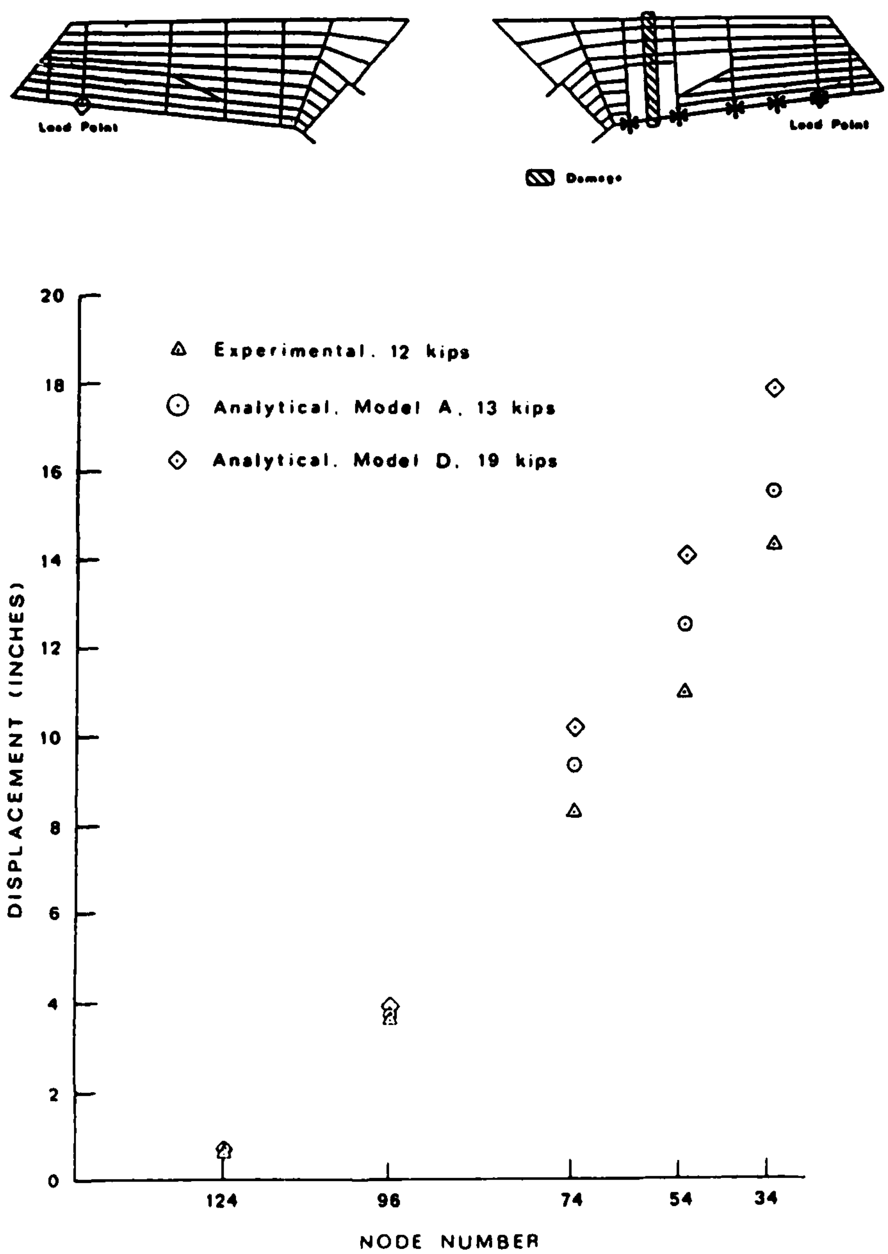
Deflections were measured in the experimental test program and were compared to analytical results. Figures 30 through 32 (Appendix I) present single-point deflection data for Models A, C, and D, and for the test program. Although Model D was selected as the best model because of its ability to predict the failure most realistically, Model A was superior for predicting displacement values. For general deflected shape, however, there was little difference between Models A and D. Figure 20 compares Test 3B profiles of the front and rear spars for Models A and D, and for the actual wing at their respective failure loads. Both models presented essentially the same deflected shape which differed only slightly from measured results.

As mentioned in the previous section, deflections are not envisioned as a critical factor in the routine application of the AFATL method. Even if deflected shape were important, Models A and D both returned approximately the same results. If specific values of displacement were to become the overriding concern in a specialized application, Model A would appear to be the better model. Otherwise, Model D provided reasonable accuracy for deflected shape.



(a) Front Spar Profile

Figure 20. Failure Load Profiles for Test 3B



(b) Rear Spar Profile

Figure 20. (Continued)

CHAPTER IX

SUMMARY AND CONCLUSIONS

The principal goal of this study was to evaluate the suitability of the AFATL method for predicting progressive collapse in complex structures. Suitability was to be investigated by determining supportable limiting stress values, selecting a good combination of finite elements for modeling, and comparing analytical to experimental results.

Limiting stresses used in this study were a direct application of classical theory. Consequently, any skilled analyst could apply the concepts to any structure. A conscious effort was made to found the work in commonly known principals of materials behavior and to avoid the structure-dependency associated with empirical formulations.

All models evaluated used axial rod and shear panel element combinations to represent spars and ribs. Model D used membrane elements to model aircraft skin and rod elements to model skin stiffeners. Additionally, it had torsional rod elements along the spar centerlines. Model A used shear panels and thickened rod elements to represent aircraft skin and skin stiffeners. Model A had no torsional rod elements.

Models A and D both overestimated the residual strength of the damaged structures. For the purposes of this study, those results were conservative. A deficiency observed in the study was the lack of consistency in the degree to which residual strength was overestimated. However, all estimates were within a factor of two of the experimental results.

Model A provided better deflection estimates than Model D. Using shear panel elements for the aircraft skin made Model A more difficult to prepare than the models using membrane elements. As explained in Appendix C, the use of shear panel elements required additional calculations for modifying rod element sizes to represent the membrane capacity of the skin. However, once Model A was developed, it was less expensive to use than models with membrane skin elements. For applications where structure displacements are of primary concern, Model A would provide better results.

Model D described more accurately the actual pattern of failure leading to structural collapse. Using membrane elements for the aircraft skin made Model D a simpler model to prepare as described in Appendix C. The membrane elements also gave a better qualitative representation of skin panel behavior. For applications where the failure pattern is of principal interest, Model D would provide better results.

PROSCAN was developed as a convenience to automate the application of the AFATL method. It proved to be more of a necessity than a convenience in processing the volumes of data generated by many iterative finite element analyses. Additionally, it provided flexibility in the selection of loading sequences and in the application of limiting stresses for elements.

The combination of automation, modeling techniques, and limiting stresses applied to the AFATL method produced a useful estimating tool for predicting progressive collapse in complex structures such as the F-84F aircraft wing. The F-84F wing is a semi-monocoque structure with a heavy two-spar skeletal frame. To further evaluate the versatility of

the method, it should also be tested using other types of structures such as different aircraft designs and components or building structures.

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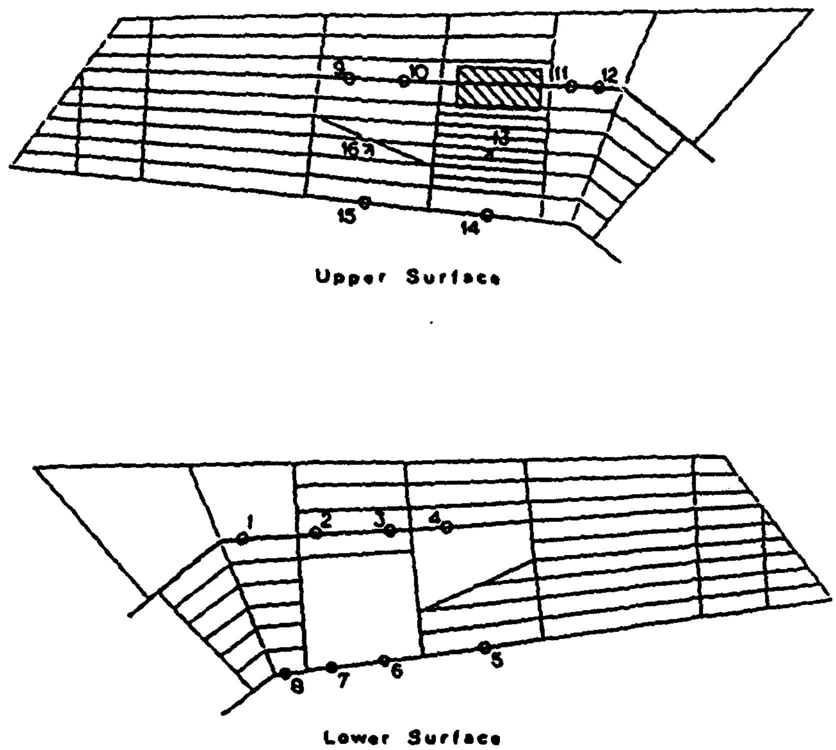
APPENDIX A

STRAIN GAGE LOCATIONS FOR EXPERIMENTAL PROGRAM

Three wings were tested in the experimental portion of the study. Surface strains were measured using strain gages manufactured by Micro-Measurements of Romulus, Michigan. Two types of gages were used: EA-13-125AD-120 uniaxial gages, and EA-13-250RA-120 three-gage rectangular rosettes. Figure 21 details strain gage locations for all three tests.

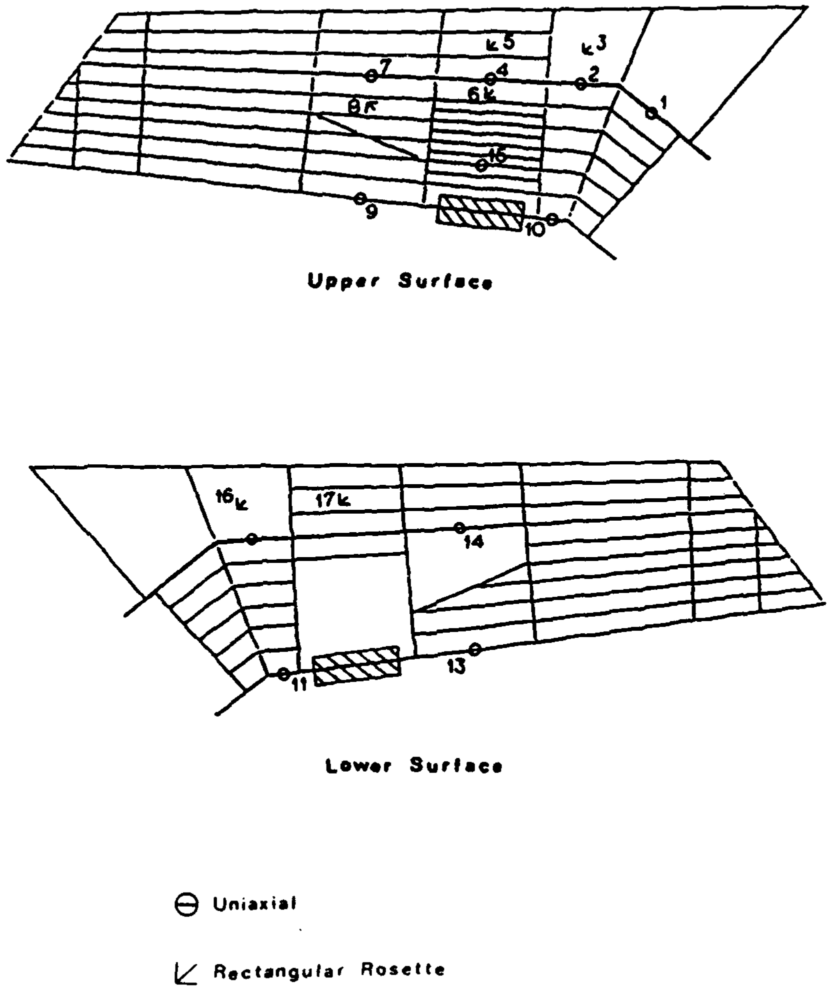


⊖ Uniaxial

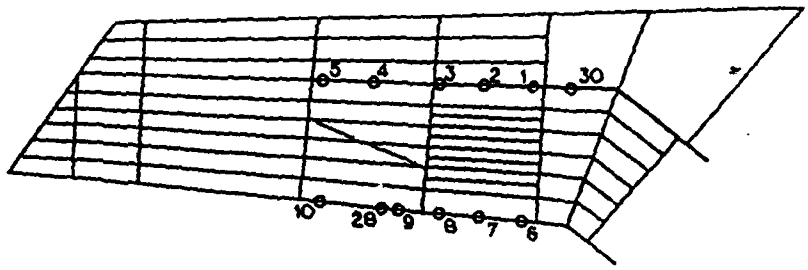
Rectangular Rosette

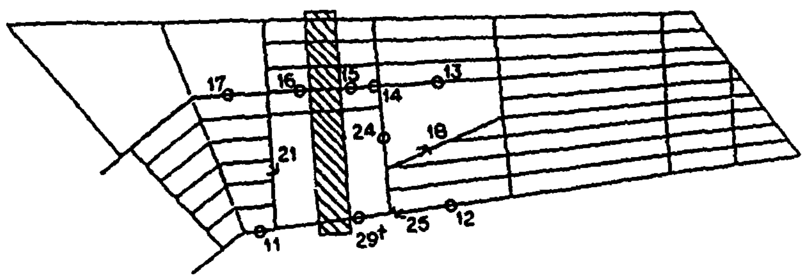
(a) Test 1

Figure 21. Strain Gage Locations



(b) Test 2

Figure 21. (Continued)

Upper Surface



Lower Surface

⊖ Uniaxial

Rectangular Rosette

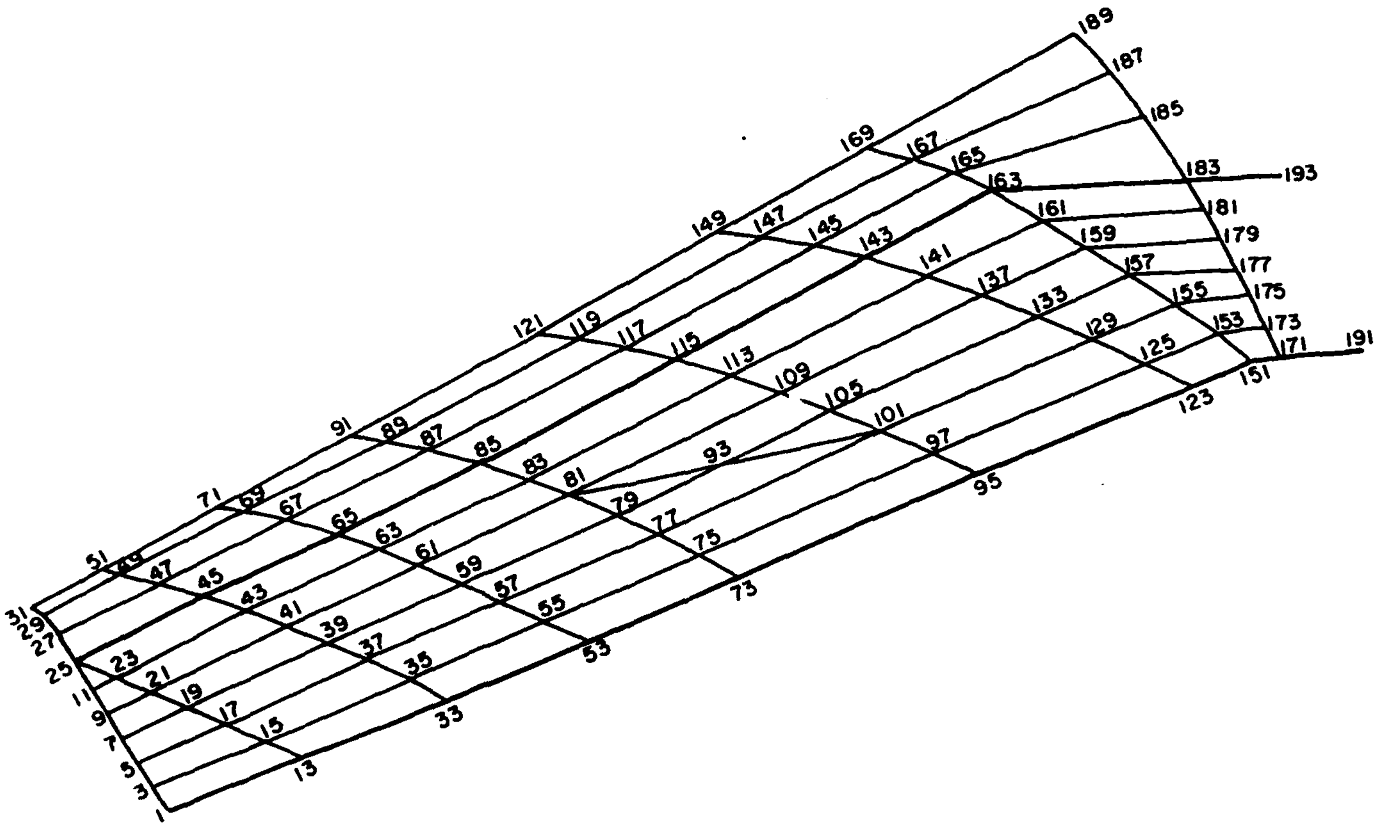
† Test 3B only

(c) Test 3

Figure 21. (Continued)

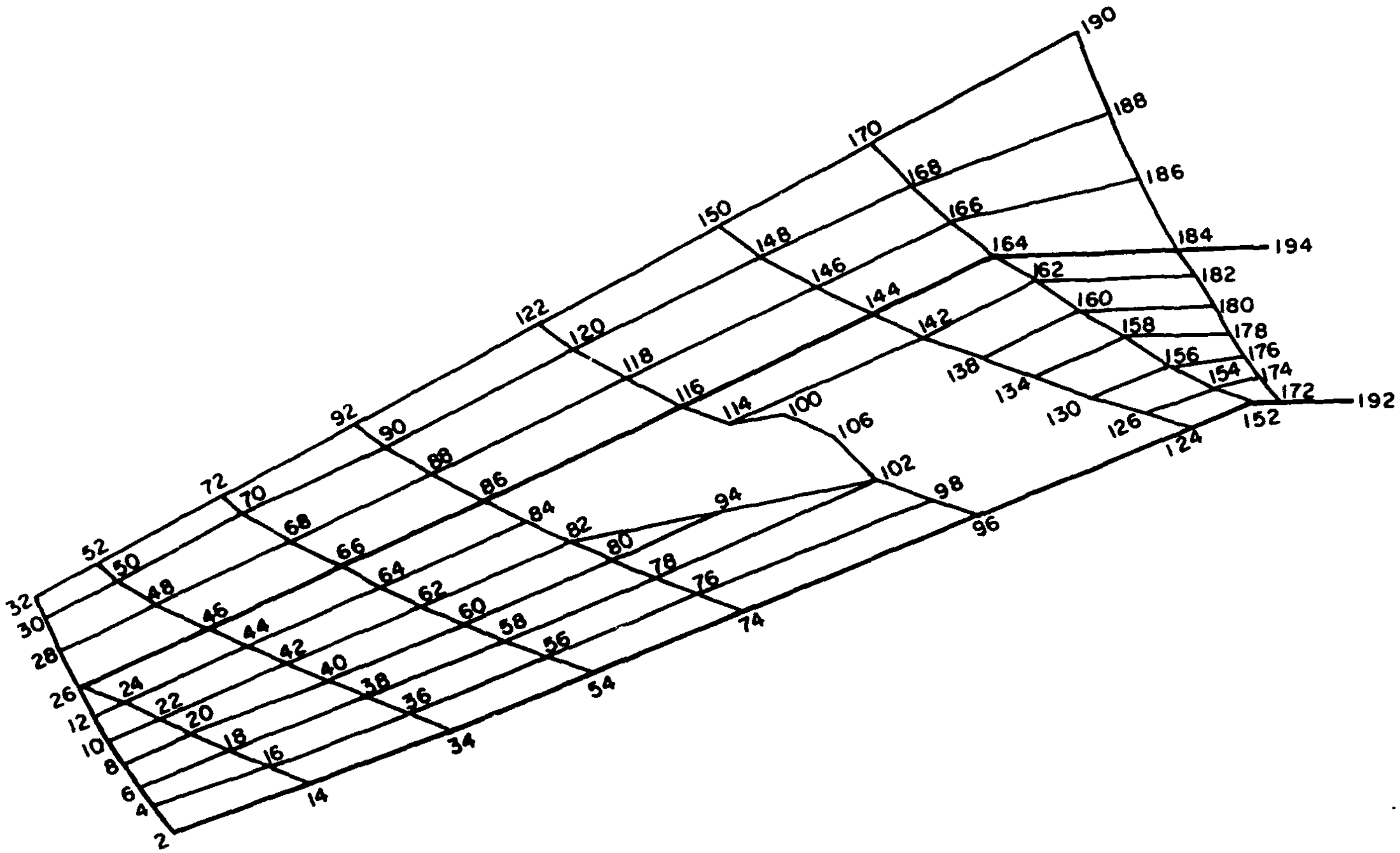
APPENDIX B

FINITE ELEMENT MODEL NUMBERING DETAILS



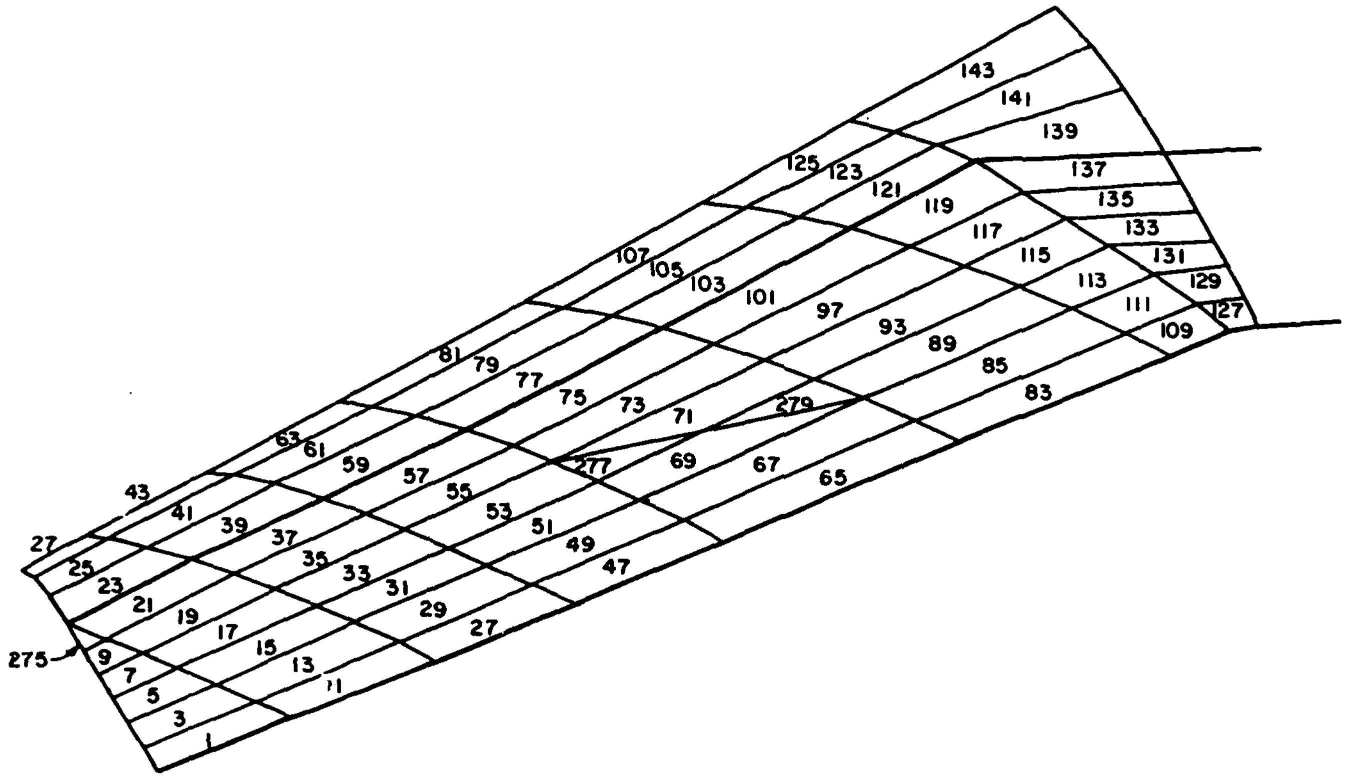
a. Node Numbers, Upper Surface

Figure 22. Finite Element Model Numbering Details



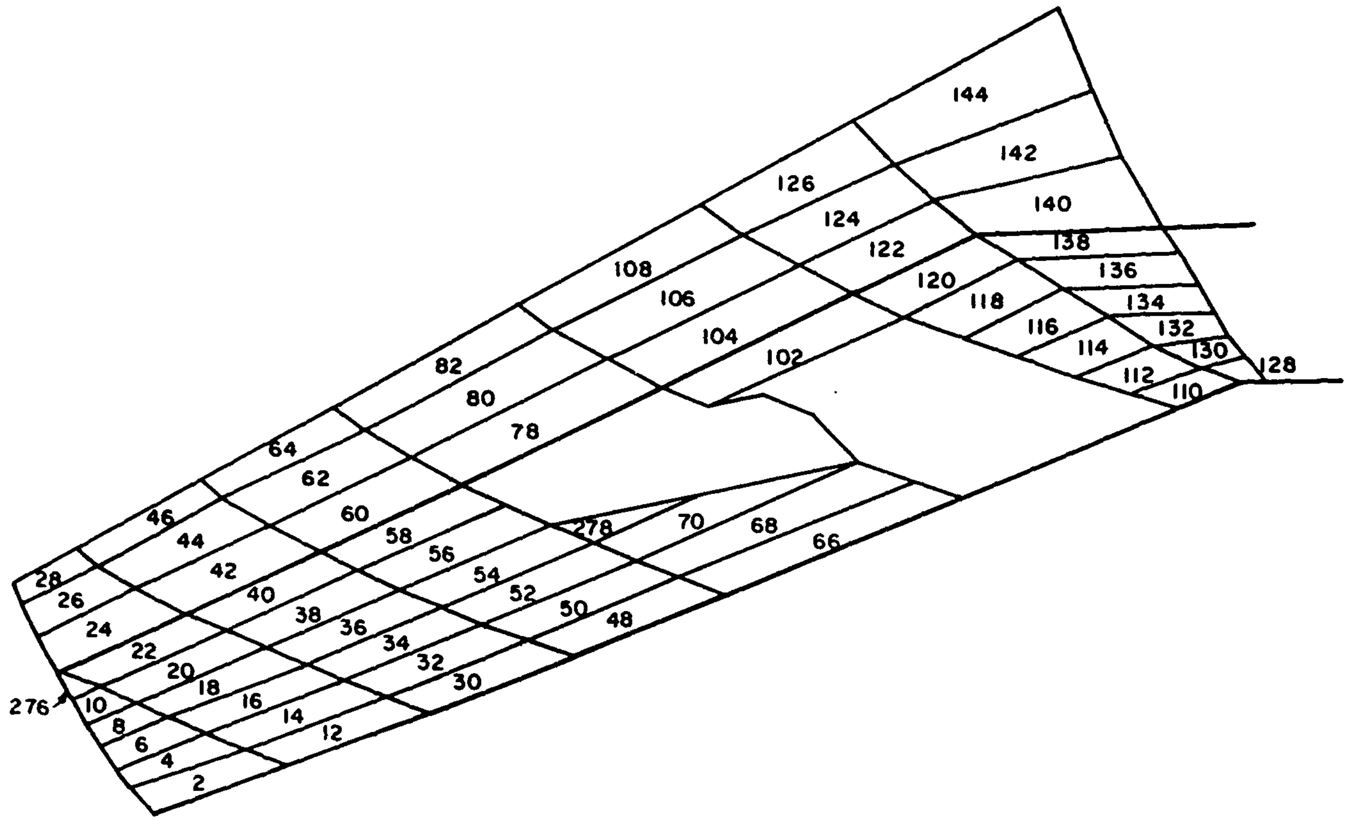
b. Node Numbers, Lower Surface

Figure 22. (Continued)



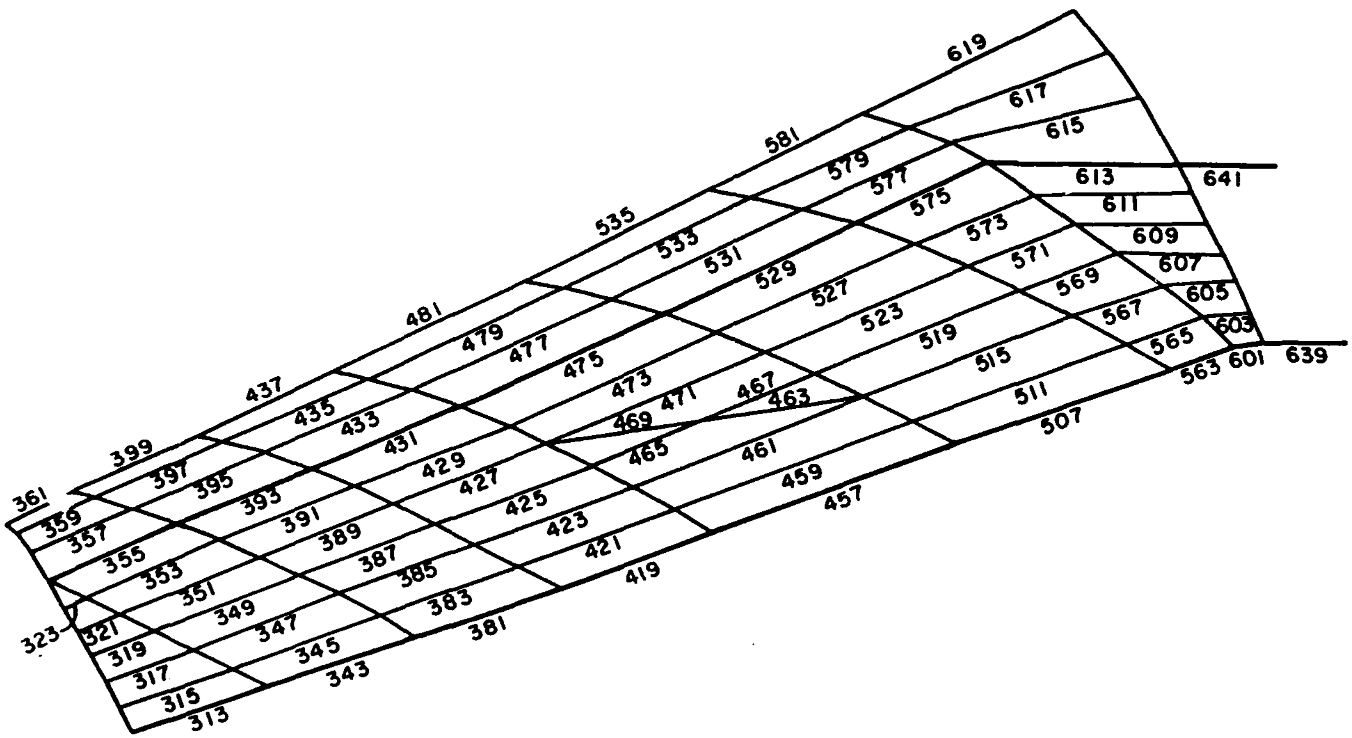
c. Skin Panels, Upper Surface

Figure 22. (Continued)



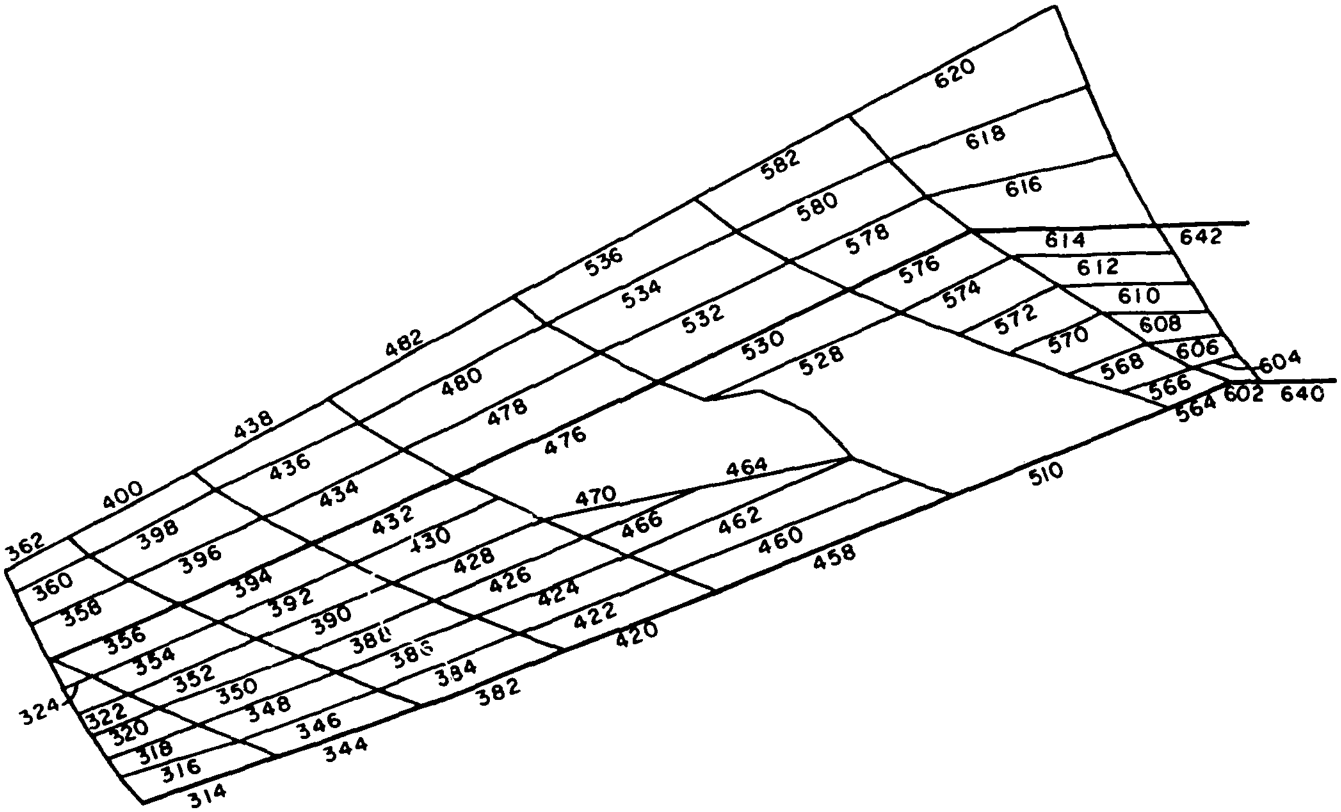
d. Skin Panels, Lower Surface

Figure 22. (Continued)



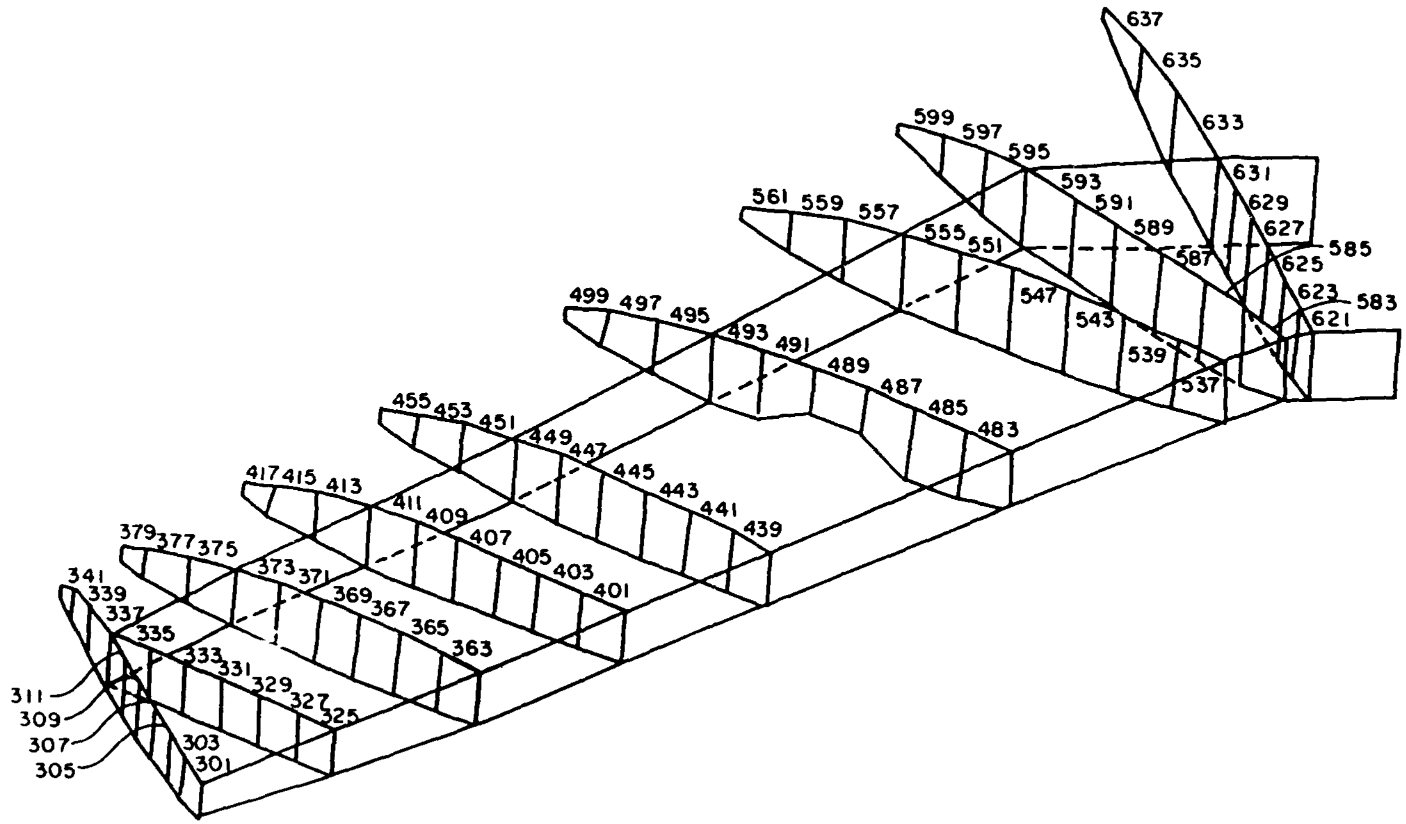
e. Spar Cap and Stiffener Rods, Upper Surface

Figure 22. (Continued)



f. Spar cap and Stiffener Rods, Lower Surface

Figure 22. (Continued)

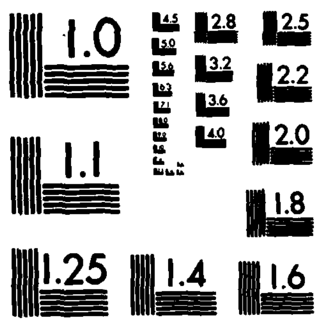


g. Rib Cap Rods, Upper Surface

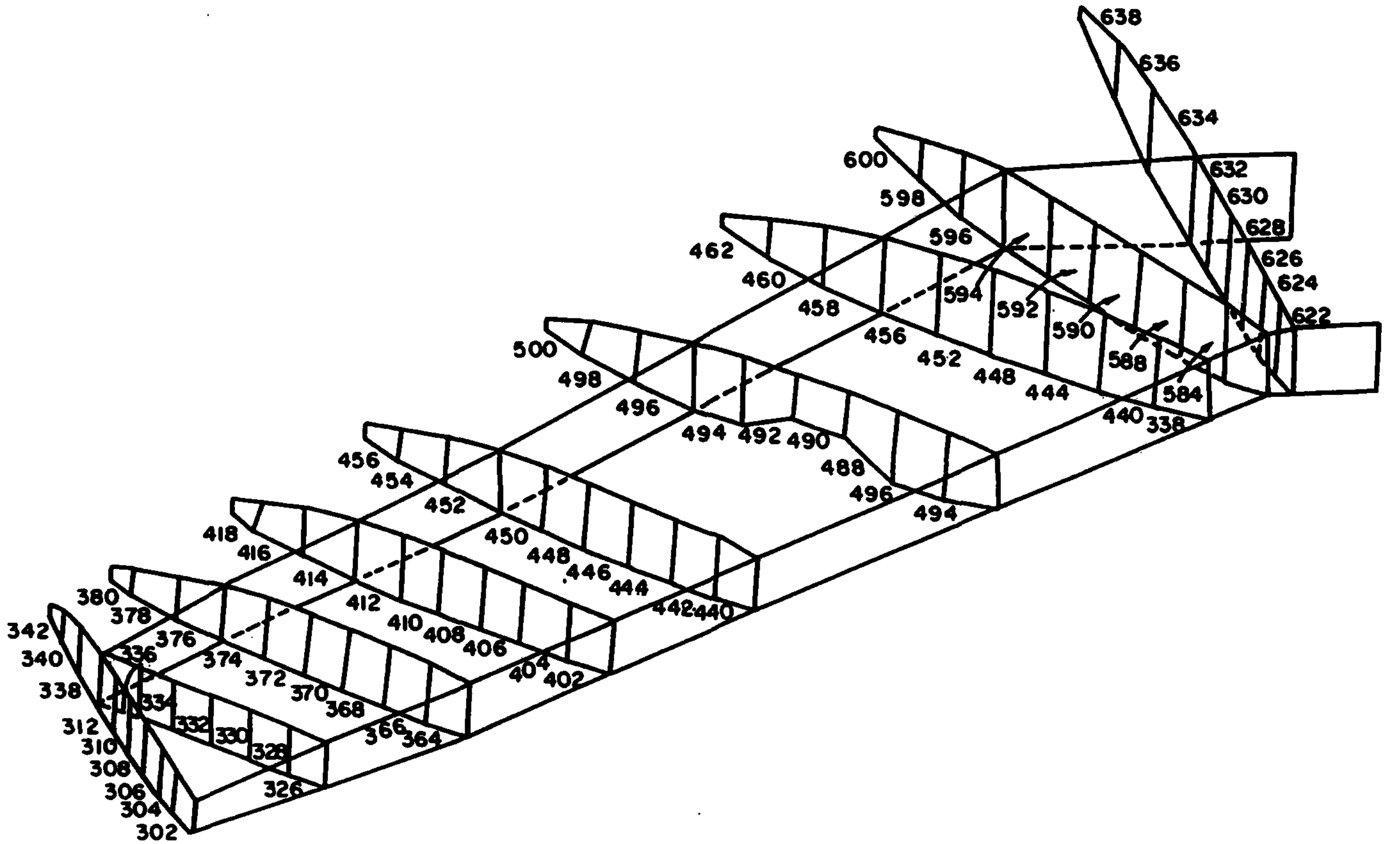
Figure 22. (Continued)

AD-A125 266 ANALYSIS OF PROGRESSIVE COLLAPSE OF COMPLEX STRUCTURES (U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH G E RIGGS DEC 82 AFIT/CI/NR-82-63D 2/3

UNCLASSIFIED F/G 12/1 NL

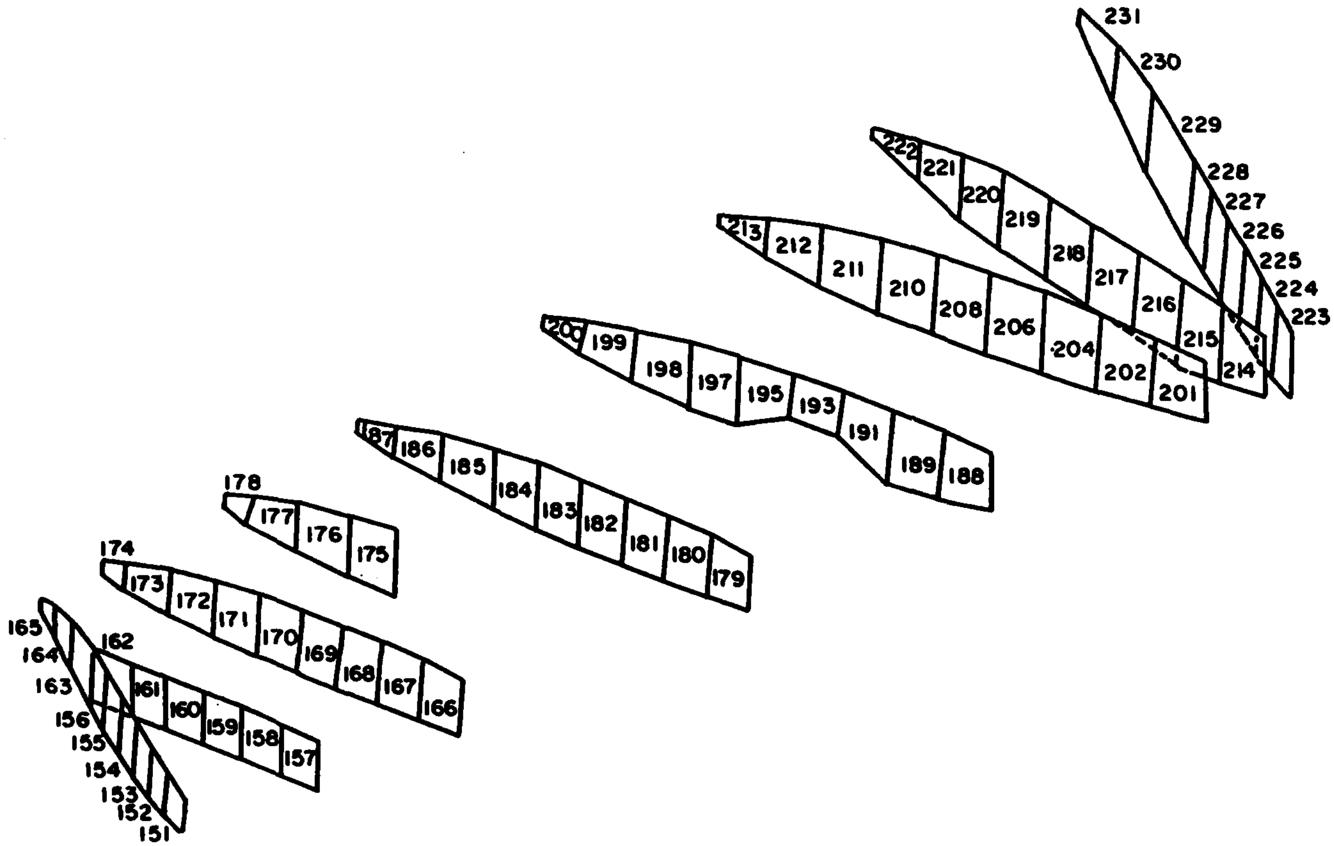


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



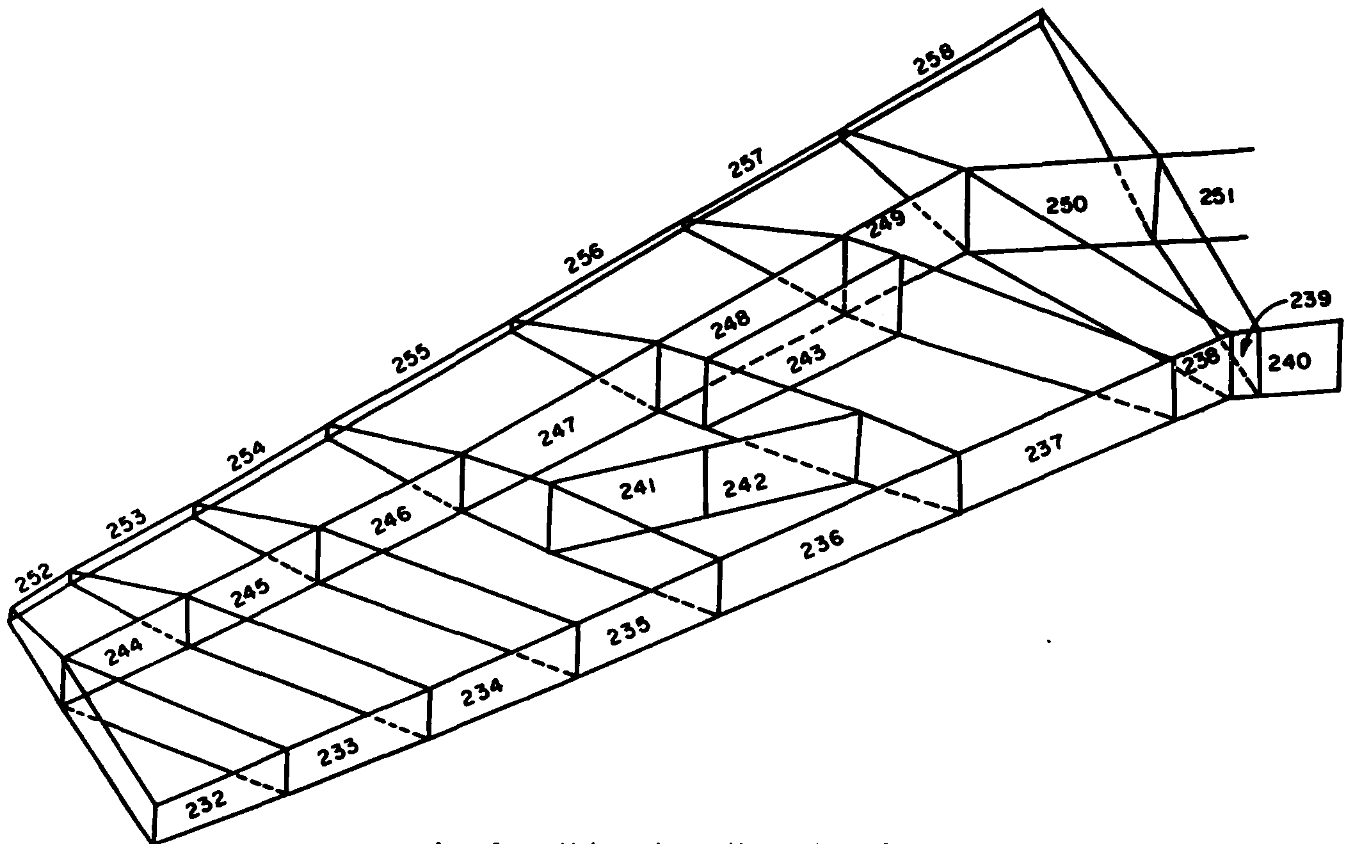
h. Rib Cap Rods, Lower Surface

Figure 22. (Continued)



i. Rib Web Elements

Figure 22. (Continued)



j. Spar Web and Leading Edge Elements

APPENDIX C

SIZING OF ROD ELEMENTS

The rationale for sizing rod elements representing spar caps or rib caps was presented by Jordan (32, 33). All symbols in the following summary of his presentation refer to Figures 23 and 24 which were extracted from Reference (32).

Property relationships were first determined for a structural member's cross section. The distance from the top surface of the section to the centroidal axis was identified as h_t. Similarly, the distance from the centroidal axis to the bottom surface of the section was labeled h_b. Maximum bending stresses at top and bottom surfaces, respectively, were

$$\sigma_T = \frac{Mh_t}{I} \tag{A.1a}$$

and

$$\sigma_B = \frac{Mh_b}{I} \tag{A.1b}$$

where M was the applied bending moment, and I was the section moment of inertia about the centroidal axis.

In the model, the rod elements were assumed to be point areas and were positioned at the top and bottom surfaces of a cross section. The rod areas were sized to maintain the location of the centroidal axis and the value of I for the actual section. Such a relationship yielded

$$A_T h_t = A_B h_b \tag{A.2}$$

with A_T and A_B being the areas of the top and bottom rods. The bending moment, M, in the model then became

$$M = \sigma_T A_T h_t + \sigma_B A_B h_b \tag{A.3}$$

Next, using actual section properties and desired model properties, the

relationships of Equations (A.1), (A.2), and (A.3) were combined to produce

$$A_T = \frac{I}{h_t(h_t + h_b)} \tag{A.4a}$$

and

$$A_B = \frac{I}{h_b(h_t + h_b)} \tag{A.4b}$$

which were the rod element areas.

Skin stiffeners also were represented by rod elements. Initially, each of those rods had the same cross sectional area and position in the structure as the stiffener it represented. However, Models A and B used shear panel elements to represent aircraft skin, so the membrane capacity of the skin panels was lost because shear panel elements do not represent membrane behavior. The membrane capacity of the skin was restored to models A and B by adding the cross sectional area of each skin panel to its bordering rod elements. This is illustrated for a typical cross section in Figure 24. Such modification of stiffener rod element areas was not necessary for Models C and D because they used membrane elements to represent the aircraft skin.

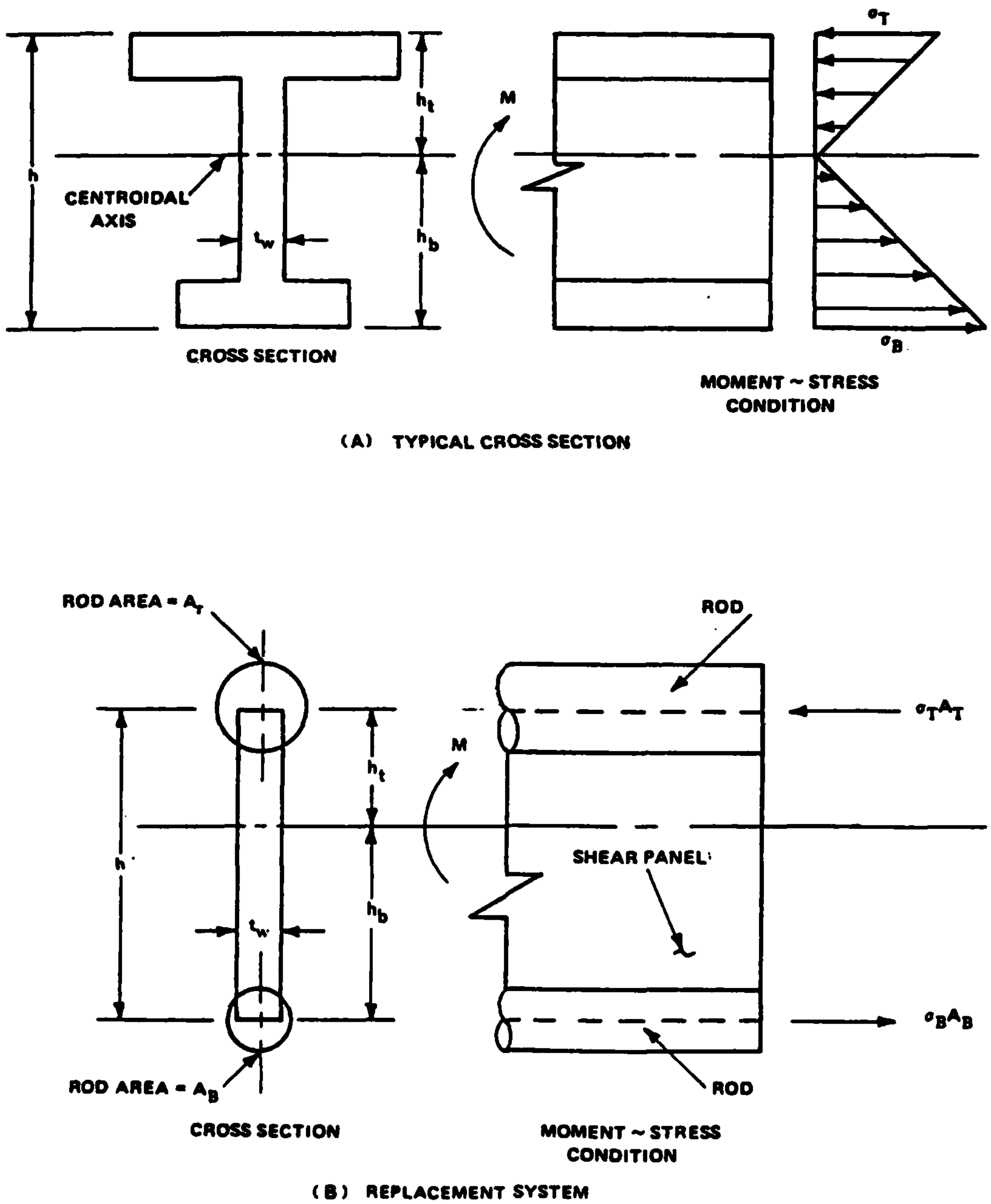


Figure 23. Basic Sizing of Rod Elements

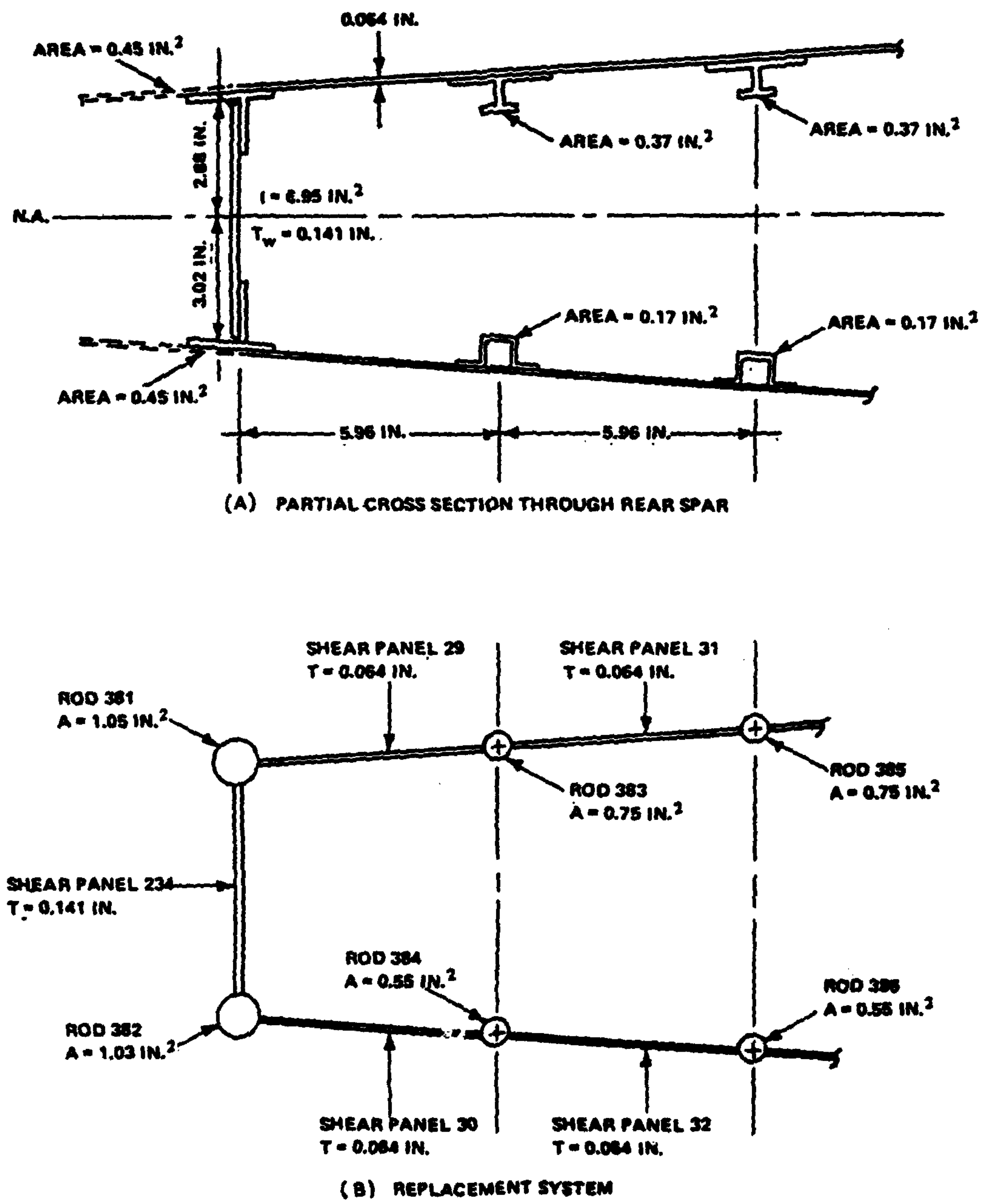


Figure 24. Rod Element Sizing With Shear Panel Skin

APPENDIX D

FINITE ELEMENT MODEL A LISTING

```
$      ***********************************************************
$      *                  BULK DATA DECK FOR                      *
$      *        F-84F WING PROJECT - UNDAMAGED WING               *
$      *              MODEL A - STATIC CASE                       *
$      *          SPARS AND RIBS:  CROD AND CSHEAR                *
$      *              STIFFENERS:  CROD                           *
$      *             SKIN PANELS:  CSHEAR                         *
$      *         NO TORSIONAL STIFFNESS IN SPARS                  *
$      ***********************************************************
$
$      THE WING ALUMINUM IS 7075-T6 EXCEPT 2024-T3 IN A FEW SKIN PANELS
$      THE WING SPAR ROOTS ARE 5 CR-MO-V AIRCRAFT STEEL
$
$      ***********************************************************
$      *                GRID POINTS - TOP OF WING                *
$      ***********************************************************
$
GRID    1               232.9   -30.4   -2.5
GRID    3               229.    -25.33  -2.9
GRID    5               225.    -20.27  -3.2
GRID    7               221.    -15.2   -3.5
GRID    9               217.    -10.13  -3.55
GRID    11              213.    -5.07   -3.45
GRID    13              209.    -32.5   -2.65
GRID    15              209.    -27.08  -3.05
GRID    17              209.    -21.67  -3.3
GRID    19              209.    -16.25  -3.55
GRID    21              209.    -10.83  -3.55
GRID    23              209.    -5.47   -3.5
GRID    25              209.    0.0     -3.25
GRID    27              203.9   6.4     -2.6
GRID    29              199.9   11.7    -1.85
GRID    31              196.8   15.6    -.5
GRID    33              184.1   -34.7   -2.85
GRID    35              184.1   -28.92  -3.25
GRID    37              184.1   -23.13  -3.65
GRID    39              184.1   -17.35  -3.9
GRID    41              184.1   -11.57  -3.8
GRID    43              184.1   -5.78   -3.65
GRID    45              184.1   0.0     -3.5
GRID    47              184.1   6.7     -2.65
GRID    49              184.1   12.1    -1.9
GRID    51              184.1   16.0    -.5
GRID    53              159.1   -36.85  -3.05
GRID    55              159.1   -30.71  -3.45
GRID    57              159.1   -24.67  -3.85
GRID    59              159.1   -18.423 -4.1
GRID    61              159.1   -12.28  -4.05
GRID    63              159.1   -6.14   -3.9
GRID    65              159.1   0.0     -3.7
GRID    67              159.1   7.0     -2.8
GRID    69              159.1   12.7    -2.
GRID    71              159.1   17.1    -.5
GRID    73              134.4   -39.    -3.3
GRID    75              133.82  -32.5   -3.7
GRID    77              133.23  -26.    -4.1
GRID    79              132.65  -19.5   -4.35
GRID    81              132.07  -13.    -4.35
GRID    83              131.48  -6.5    -4.2
GRID    85              130.9   0.0     -4.
GRID    87              130.9   7.4     -3.0
GRID    89              130.9   13.4    -2.1
GRID    91              130.9   18.3    -.5
GRID    93              111.35  -20.43  -4.58
GRID    95              91.8    -42.7   -3.6
GRID    97              91.8    -35.58  -4.
GRID    101             91.8    -28.47  -4.35
GRID    105             91.8    -21.35  -4.6
GRID    109             91.8    -14.23  -4.75
GRID    113             91.8    -7.12   -4.9
GRID    115             91.8    0.0     -4.35
GRID    117             91.8    8.0     -3.3
GRID    119             91.8    14.4    -2.25
GRID    121             91.8    20.     -.5
GRID    123             54.     -46.3   -4.
GRID    125             54.     -38.58  -4.35
GRID    129             54.     -30.87  -4.85
GRID    133             54.     -23.15  -5.15
GRID    137             54.     -15.43  -5.1
GRID    141             54.     -7.72   -4.85
GRID    143             54.     0.0     -4.7
GRID    145             54.     8.5     -3.55
GRID    147             54.     15.4    -2.4
GRID    149             54.     21.6    -.5
GRID    151             43.8    -47.2   -4.
GRID    153             41.43   -39.33  -4.5
GRID    155             39.07   -31.47  -4.95
GRID    157             36.7    -23.6   -5.25
GRID    159             34.33   -15.73  -5.35
GRID    161             31.97   -7.87   -5.1
GRID    163             29.6    0.0     -5.
GRID    165             27.3    7.7     -4.
GRID    167             25.     15.3    -2.8
GRID    169             22.7    23.     -.5
GRID    171             41.1    -49.    -4.
GRID    173             36.28   -43.27  -4.3
GRID    175             31.47   -37.83  -4.75
GRID    177             26.65   -31.8   -5.15
GRID    179             21.83   -26.07  -5.4
GRID    181             17.02   -20.33  -5.45
GRID    183             12.7    -14.6   -5.45
GRID    185             .5      -.5     -5.
GRID    187             -10.    11.5    -3.6
GRID    189             -21.5   24.6    -.5
GRID    191             32.7    -56.1   -2.95
GRID    193             3.3     -32.1   -5.
$
$      ***********************************************************
$      *               GRID POINTS - BOTTOM OF WING              *
$      ***********************************************************
$
GRID    2               232.9   -30.4   2.5
GRID    4               229.    -25.33  2.9
GRID    6               225.    -20.27  3.2
GRID    8               221.    -15.2   3.5
GRID    10              217.    -10.13  3.55
GRID    12              213.    -5.07   3.45
GRID    14              209.    -32.5   2.65
GRID    16              209.    -27.08  3.05
GRID    18              209.    -21.67  3.3
GRID    20              209.    -16.25  3.55
GRID    22              209.    -10.83  3.55
GRID    24              209.    -5.42   3.5
GRID    26              209.    0.0     3.25
GRID    28              204.3   6.0     2.6
GRID    30              199.2   12.8    1.85
GRID    32              196.8   15.6    .5
GRID    34              184.1   -34.7   2.85
GRID    36              184.1   -28.92  3.25
GRID    38              184.1   -23.13  3.65
GRID    40              184.1   -17.35  3.9
GRID    42              184.1   -11.57  3.8
GRID    44              184.1   -5.78   3.65
GRID    46              184.1   0.0     3.5
GRID    48              184.1   6.2     2.65
GRID    50              184.1   12.0    1.9
GRID    52              184.1   16.0    .5
GRID    54              159.1   -36.85  3.05
GRID    56              159.1   -30.71  3.45
GRID    58              159.1   -24.67  3.85
GRID    60              159.1   -18.425 4.1
GRID    62              159.1   -12.28  4.05
GRID    64              159.1   -6.14   3.9
GRID    66              159.1   0.0     3.7
GRID    68              159.1   6.6     2.8
GRID    70              159.1   12.8    2.
GRID    72              159.1   17.1    .5
GRID    74              134.4   -39.    3.3
GRID    76              133.82  -32.5   3.7
GRID    78              133.23  -26.    4.1
GRID    80              132.65  -19.5   4.35
GRID    82              132.07  -13.    4.35
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GRID    84              131.48  -6.5    4.2
GRID    86              130.9   0.0     4.
GRID    88              130.9   7.0     3.0
GRID    90              130.9   14.7    2.1
GRID    92              130.9   18.3    .5
GRID    94              111.36  -20.43  4.58
GRID    96              91.8    -42.7   3.6
GRID    98              91.8    -36.58  4.
GRID    102             91.8    -28.47  4.35
GRID    106             91.8    -21.38  .75
GRID    110             91.8    -14.23  .70
GRID    114             91.8    -7.12   4.5
GRID    116             91.8    0.0     4.35
GRID    118             91.8    7.6     3.3
GRID    120             91.8    16.     2.25
GRID    122             91.8    20.     .5
GRID    124             54.     -46.3   4.
GRID    126             54.     -36.58  4.35
GRID    130             54.     -30.87  4.85
GRID    134             54.     -23.15  5.15
GRID    138             54.     -15.43  5.1
GRID    142             54.     -7.72   4.85
GRID    144             54.     0.0     4.7
GRID    146             54.     8.3     3.58
GRID    148             54.     17.2    2.4
GRID    150             54.     21.6    .5
GRID    152             43.8    -47.2   4.
GRID    154             41.43   -39.33  4.8
GRID    156             39.07   -31.47  4.95
GRID    158             36.7    -23.6   5.25
GRID    160             34.33   -15.73  5.35
GRID    162             31.97   -7.87   5.1
GRID    164             29.6    0.0     5.
GRID    166             27.3    7.7     4.
GRID    168             25.     16.3    2.8
GRID    170             22.7    23.     .5
GRID    172             41.1    -49.    4.
GRID    174             36.38   -43.27  4.3
GRID    176             31.47   -37.53  4.75
GRID    178             26.65   -31.8   5.15
GRID    180             21.83   -26.07  5.4
GRID    182             17.02   -20.33  5.45
GRID    184             12.7    -14.6   5.45
GRID    186             .5      -.5     5.
GRID    188             -10.    11.5    3.6
GRID    190             -21.5   24.6    .5
GRID    192             33.7    -56.1   3.95
GRID    194             3.8     -21.7   5.
$
$       ********************************************************
$       *               SHEAR PANELS - TOP OF WING             *
$       ********************************************************
$
CSHEAR  1       222251  1       3       15      13
CSHEAR  3       1       3       5       17      15
CSHEAR  5       1       5       7       19      17
CSHEAR  7       1       7       9       21      19
CSHEAR  9       1       9       11      23      21
CSHEAR  11      222251  13      15      35      33
CSHEAR  13      1       15      17      37      35
CSHEAR  15      1       17      19      39      37
CSHEAR  17      1       19      21      41      39
CSHEAR  19      1       21      23      43      41
CSHEAR  21      222251  23      25      45      43
CSHEAR  23      222251  25      27      47      45
CSHEAR  25      1       27      29      49      47
CSHEAR  27      1       29      31      51      49
CSHEAR  29      222251  33      35      55      53
CSHEAR  31      1       35      37      57      55
CSHEAR  33      1       37      39      59      57
CSHEAR  35      1       39      41      61      59
CSHEAR  37      1       41      43      63      61
CSHEAR  39      222251  43      45      65      63
CSHEAR  41      222251  45      47      67      65
CSHEAR  43      1       47      49      69      67
CSHEAR  45      1       49      51      71      69
CSHEAR  47      222251  53      55      75      73
CSHEAR  49      1       55      57      77      75
CSHEAR  51      1       57      59      79      77
CSHEAR  53      1       59      61      81      79
CSHEAR  55      1       61      63      83      81
CSHEAR  57      222251  63      65      85      83
CSHEAR  59      222251  65      67      87      85
CSHEAR  61      1       67      69      89      87
CSHEAR  63      1       69      71      91      89
CSHEAR  65      222252  73      75      97      95
CSHEAR  67      2       75      77      101     97
CSHEAR  69      222252  77      79      93      101
CSHEAR  71      222252  93      81      109     105
CSHEAR  73      2       81      83      113     109
CSHEAR  75      222252  83      85      115     113
CSHEAR  77      222252  85      87      117     115
CSHEAR  79      2       87      89      119     117
CSHEAR  81      2       89      91      121     119
CSHEAR  83      222252  95      97      125     123
CSHEAR  85      2       97      101     129     125
CSHEAR  89      2       101     105     133     129
CSHEAR  93      2       105     109     137     133
CSHEAR  97      2       109     113     141     137
CSHEAR  101     222252  113     115     143     141
CSHEAR  103     222252  115     117     145     143
CSHEAR  105     2       117     119     147     145
CSHEAR  107     2       119.    121     149     147
CSHEAR  109     222252  123     125     153     151
CSHEAR  111     2       125     129     155     153
CSHEAR  113     2       129     133     157     155
CSHEAR  115     2       133     137     159     157
CSHEAR  117     2       137     141     161     159
CSHEAR  119     222252  141     143     163     161
CSHEAR  121     222252  143     145     165     163
CSHEAR  123     4       145     147     167     165
CSHEAR  125     4       147     149     169     167
CSHEAR  127     222252  151     153     173     171
CSHEAR  129     2       153     155     175     173
CSHEAR  131     2       155     157     177     175
CSHEAR  133     2       157     159     179     177
CSHEAR  135     2       159     161     181     179
CSHEAR  137     222252  161     163     183     181
CSHEAR  139     222252  163     165     185     183
CSHEAR  141     4       165     167     187     185
CSHEAR  143     4       167     169     189     187
$
$       ********************************************************
$       *               SHEAR PANELS - BOTTOM OF WING          *
$       ********************************************************
$
CSHEAR  2       222251  2       4       16      14
CSHEAR  4       1       4       6       18      16
CSHEAR  6       1       6       8       20      18
CSHEAR  8       1       8       10      22      20
CSHEAR  10      1       10      12      24      22
CSHEAR  12      222251  14      16      36      34
CSHEAR  14      1       16      18      38      36
CSHEAR  16      1       18      20      40      38
CSHEAR  18      1       20      22      42      40
CSHEAR  20      1       22      24      44      42
CSHEAR  22      222251  24      26      46      44
CSHEAR  24      222251  26      28      48      46
CSHEAR  26      1       28      30      50      48
CSHEAR  28      1       30      32      52      50
CSHEAR  30      222251  34      36      56      54
CSHEAR  32      1       36      38      58      56
CSHEAR  34      1       38      40      60      58
CSHEAR  36      1       40      42      62      60
CSHEAR  38      1       42      44      64      62
CSHEAR  40      222251  44      46      66      64
CSHEAR  42      222251  46      48      68      66
CSHEAR  44      1       48      50      70      68
CSHEAR  46      1       50      52      72      70
CSHEAR  48      222251  54      56      76      74
CSHEAR  50      1       56      58      78      76
CSHEAR  52      1       58      60      80      78
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CSHEAR  54      1       60      62      82      80
CSHEAR  56      1       62      64      84      82
CSHEAR  58      222251  64      66      86      84
CSHEAR  60      222251  66      68      88      86
CSHEAR  62      1       68      70      90      88
CSHEAR  64      1       70      72      92      90
CSHEAR  66      222251  74      76      98      96
CSHEAR  68      1       76      78      102     98
CSHEAR  70      222251  78      80      94      102
CSHEAR  78      222252  86      88      118     116
CSHEAR  80      2       88      90      120     118
CSHEAR  82      2       90      92      122     120
CSHEAR  102     222252  114     116     144     142
CSHEAR  104     222252  116     118     146     144
CSHEAR  106     2       118     120     148     146
CSHEAR  108     2       120     122     150     148
CSHEAR  110     222252  124     126     154     152
CSHEAR  112     4       126     130     156     154
CSHEAR  114     4       130     134     158     156
CSHEAR  116     4       134     138     160     158
CSHEAR  118     4       138     142     162     160
CSHEAR  120     222252  142     144     164     162
CSHEAR  122     222252  144     146     166     164
CSHEAR  124     4       146     148     168     166
CSHEAR  126     4       148     150     170     168
CSHEAR  128     222252  152     154     174     172
CSHEAR  130     4       154     156     176     174
CSHEAR  132     4       156     158     178     176
CSHEAR  134     4       158     160     180     178
CSHEAR  136     4       160     162     182     180
CSHEAR  138     222252  162     164     184     182
CSHEAR  140     222252  164     166     186     184
CSHEAR  142     4       166     168     188     186
CSHEAR  144     4       168     170     190     188
$
$     ***********************************************************
$     *                 VERTICAL SHEAR PANELS                   *
$     ***********************************************************
$
$     RIBS
CSHEAR  151     2222104 1       2       4       3
CSHEAR  152     2222104 3       4       6       5
CSHEAR  153     2222104 5       6       8       7
CSHEAR  154     2222104 7       8       10      9
CSHEAR  155     2222104 9       10      12      11
CSHEAR  156     2222104 11      12      26      25
CSHEAR  157     2222105 13      14      16      15
CSHEAR  158     2222105 15      16      18      17
CSHEAR  159     2222105 17      18      20      19
CSHEAR  160     2222105 19      20      22      21
CSHEAR  161     2222105 21      22      24      23
CSHEAR  162     2222106 23      24      26      25
CSHEAR  163     2222106 25      26      28      27
CSHEAR  164     2222106 27      28      30      29
CSHEAR  165     2222106 29      30      32      31
CSHEAR  166     2222107 33      34      36      35
CSHEAR  167     2222107 35      36      38      37
CSHEAR  168     2222107 37      38      40      39
CSHEAR  169     2222107 39      40      42      41
CSHEAR  170     2222107 41      42      44      43
CSHEAR  171     2222107 43      44      46      45
CSHEAR  172     2222108 45      46      48      47
CSHEAR  173     2222108 47      48      50      49
CSHEAR  174     2222108 49      50      52      51
CSHEAR  175     2222203 63      64      66      65
CSHEAR  176     2222203 65      66      68      67
CSHEAR  177     2222203 67      68      70      69
CSHEAR  178     2222203 69      70      72      71
CSHEAR  179     2222203 73      74      76      75
CSHEAR  180     2222203 75      76      78      77
CSHEAR  181     2222203 77      78      80      79
CSHEAR  182     2222203 79      80      82      81
CSHEAR  183     2222203 81      82      84      83
CSHEAR  184     2222203 83      84      86      85
CSHEAR  185     2222204 85      86      88      87
CSHEAR  186     2222204 87      88      90      89
CSHEAR  187     2222304 89      90      92      91
CSHEAR  188     2222403 95      96      98      97
CSHEAR  189     2222403 97      98      102     101
CSHEAR  191     2222404 101     102     106     105
CSHEAR  193     2222404 105     106     110     109
CSHEAR  195     2222403 109     110     114     113
CSHEAR  197     2222403 113     114     116     115
CSHEAR  198     2222405 115     116     118     117
CSHEAR  199     2222405 117     118     120     119
CSHEAR  200     2222405 119     120     122     121
CSHEAR  201     2222503 123     124     126     125
CSHEAR  202     2222503 125     126     130     129
CSHEAR  204     2222503 129     130     134     133
CSHEAR  206     2222503 133     134     138     137
CSHEAR  208     2222503 137     138     142     141
CSHEAR  210     2222503 141     142     144     143
CSHEAR  211     2222504 143     144     146     145
CSHEAR  212     2222504 145     146     148     147
CSHEAR  213     2222504 147     148     150     149
CSHEAR  214     2222602 151     152     154     153
CSHEAR  215     2222602 153     154     156     155
CSHEAR  216     2222602 155     156     158     157
CSHEAR  217     2222602 157     158     160     159
CSHEAR  218     2222602 159     160     162     161
CSHEAR  219     2222602 161     162     164     163
CSHEAR  220     2222603 163     164     166     165
CSHEAR  221     2222603 165     166     168     167
CSHEAR  222     2222603 167     168     170     169
CSHEAR  223     2222701 171     172     174     173
CSHEAR  224     2222701 173     174     176     175
CSHEAR  225     2222701 175     176     178     177
CSHEAR  226     2222701 177     178     180     179
CSHEAR  227     2222701 179     180     182     181
CSHEAR  228     2222701 181     182     184     183
CSHEAR  229     2222702 183     184     186     185
CSHEAR  230     2222702 185     186     188     187
CSHEAR  231     2222702 187     188     190     189
$     REAR SPAR
CSHEAR  232     2222101 1       2       14      13
CSHEAR  233     2222101 13      14      34      33
CSHEAR  234     2222101 53      33      34      54
CSHEAR  235     2222201 73      53      54      74
CSHEAR  236     2222301 95      73      74      96
CSHEAR  237     2222401 123     95      96      124
CSHEAR  238     2222502 151     123     124     152
CSHEAR  239     2222602 171     151     152     172
CSHEAR  240     2222603 191     171     172     192
$     WHEEL WELL
CSHEAR  241     2222305 93      81      82      94
CSHEAR  242     2222305 101     93      94      102
CSHEAR  243     15      141     113     114     142
$     FRONT SPAR
CSHEAR  244     2222102 45      25      26      46
CSHEAR  245     2222103 65      45      46      66
CSHEAR  246     2222202 85      65      66      86
CSHEAR  247     2222302 115     85      86      116
CSHEAR  248     2222402 143     115     116     144
CSHEAR  249     2222501 163     143     144     164
CSHEAR  250     2222601 183     163     164     184
CSHEAR  251     2222603 193     183     184     194
$     LEADING EDGE
CSHEAR  252     1       51      31      32      52
CSHEAR  253     1       71      51      52      72
CSHEAR  254     1       91      71      72      92
CSHEAR  255     2       121     91      92      122
CSHEAR  256     2       149     121     122     150
CSHEAR  257     4       169     149     150     170
CSHEAR  258     4       189     169     170     190
$
$     ***********************************************************
$     *         PROPERTY CARDS FOR WEBS OF SPARS AND RIBS       *
$     ***********************************************************
$
$       AWAY FROM DAMAGE:             BORDERING DAMAGE:
PSHEAR  2222101 11      .141          3333101 21      .141
PSHEAR  2222102 11      .329          3333102 21      .329
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```
PSHEAR  2222103 11      .406            3333103 21      .406
PSHEAR  2222104 11      .066            3333104 21      .066
PSHEAR  2222105 11      .080            3333105 21      .080
PSHEAR  2222106 11      .086            3333106 21      .086
PSHEAR  2222107 11      .140            3333107 21      .140
PSHEAR  2222201 12      .141            3333201 22      .141
PSHEAR  2222202 12      .406            3333202 22      .406
PSHEAR  2222203 12      .098            3333203 22      .098
PSHEAR  2222301 13      .219            3333301 23      .219
PSHEAR  2222302 13      .300            3333302 23      .300
PSHEAR  2222303 13      .212            3333303 23      .212
PSHEAR  2222304 13      .190            3333304 23      .190
PSHEAR  2222305 13      .182            3333305 23      .182
PSHEAR  2222401 14      .200            3333401 24      .200
PSHEAR  2222402 14      .248            3333402 24      .248
PSHEAR  2222403 14      .190            3333403 24      .190
PSHEAR  2222404 14      .411            3333404 24      .411
PSHEAR  2222405 14      .190            3333405 24      .190
PSHEAR  2222501 15      .371            3333501 25      .371
PSHEAR  2222502 15      .400            3333502 25      .400
PSHEAR  2222503 15      .204            3333503 25      .204
PSHEAR  2222504 15      .190            3333504 25      .190
PSHEAR  2222601 16      .320            3333601 26      .320
PSHEAR  2222602 16      .263            3333602 26      .263
PSHEAR  2222603 16      .300            3333603 26      .300
PSHEAR  2222701 17      .087            3333701 27      .087
PSHEAR  2222702 17      .065            3333702 27      .065
PSHEAR  2222801 18      .190            3333801 28      .190
PSHEAR  2222802 18      .400            3333802 28      .400
PSHEAR  2222803 18      .500            3333803 28      .500
$
$       ****************************************************************
$       *   PROPERTY CARDS FOR UNBUCKLED SKIN PANELS AWAY FROM DAMAGE   *
$       ****************************************************************
$
PSHEAR  1       1       .084            2       1       .081
PSHEAR  3       1       .128            4       1       .081
PSHEAR  5       1       .066            6       1       .05
PSHEAR  7       1       .14             8       1       .212
PSHEAR  9       1       .15             10      1       .411
PSHEAR  11      1       .204            12      1       .263
PSHEAR  13      1       .087            14      1       .182
PSHEAR  15      1       .1              16      1       .095
PSHEAR  17      1       .19             18      1       .3
PSHEAR  19      1       .065            20      1       .329
PSHEAR  21      1       .406            22      1       .141
PSHEAR  23      1       .219            24      1       .30
PSHEAR  25      1       .2              26      1       .246
PSHEAR  27      1       .371            28      1       .4
PSHEAR  29      1       .32             30      1       .5
PSHEAR  31      1       .15
$
$       ****************************************************************
$       * PROPERTY CARDS FOR UNBUCKLED SKIN PANELS ADJACENT TO DAMAGE   *
$       ****************************************************************
$
PSHEAR  11111   2       .084            11112   2       .081
PSHEAR  11113   2       .128            11114   2       .081
PSHEAR  11115   2       .066            11116   2       .05
PSHEAR  11117   2       .14             11118   2       .212
PSHEAR  11119   2       .15             111110  2       .411
PSHEAR  111111  2       .204            111112  2       .263
PSHEAR  111113  2       .087            111114  2       .182
PSHEAR  111115  2       .1              111116  2       .095
PSHEAR  111117  2       .19             111118  2       .3
PSHEAR  111119  2       .065            111120  2       .329
PSHEAR  111121  2       .406            111122  2       .141
PSHEAR  111123  2       .219            111124  2       .30
PSHEAR  111125  2       .2              111126  2       .246
PSHEAR  111127  2       .371            111128  2       .4
PSHEAR  111129  2       .32             111130  2       .5
PSHEAR  111131  2       .15
$
$       ****************************************************************
$       *    PROPERTY CARDS FOR BUCKLED SKIN PANELS AWAY FROM DAMAGE    *
$       ****************************************************************
$
PSHEAR  22221   3       .084            22222   3       .081
PSHEAR  22223   3       .128            22224   3       .081
PSHEAR  22225   3       .066            22226   3       .05
PSHEAR  22227   3       .14             22228   3       .212
PSHEAR  22229   3       .15             222210  3       .411
PSHEAR  222211  3       .204            222212  3       .263
PSHEAR  222213  3       .087            222214  3       .182
PSHEAR  222215  3       .1              222216  3       .095
PSHEAR  222217  3       .19             222218  3       .3
PSHEAR  222219  3       .065            222220  3       .329
PSHEAR  222221  3       .406            222222  3       .141
PSHEAR  222223  3       .219            222224  3       .30
PSHEAR  222225  3       .2              222226  3       .246
PSHEAR  222227  3       .371            222228  3       .4
PSHEAR  222229  3       .32             222230  3       .5
PSHEAR  222231  3       .15
PSHEAR  222251  5       .084            222252  5       .081
$
$       ****************************************************************
$       *  PROPERTY CARDS FOR BUCKLED SKIN PANELS ADJACENT TO DAMAGE    *
$       ****************************************************************
$
PSHEAR  33331   4       .084            33332   4       .081
PSHEAR  33333   4       .128            33334   4       .081
PSHEAR  33335   4       .066            33336   4       .05
PSHEAR  33337   4       .14             33338   4       .212
PSHEAR  33339   4       .15             333310  4       .411
PSHEAR  333311  4       .204            333312  4       .263
PSHEAR  333313  4       .087            333314  4       .182
PSHEAR  333315  4       .1              333316  4       .095
PSHEAR  333317  4       .19             333318  4       .3
PSHEAR  333319  4       .065            333320  4       .329
PSHEAR  333321  4       .406            333322  4       .141
PSHEAR  333323  4       .219            333324  4       .30
PSHEAR  333325  4       .2              333326  4       .246
PSHEAR  333327  4       .371            333328  4       .4
PSHEAR  333329  4       .32             333330  4       .5
PSHEAR  333331  4       .15
PSHEAR  333351  6       .084            333352  6       .081
$
$       ****************************************************************
$       *         PROPERTY CARDS FOR SKIN PANELS WHICH HAVE FAILED      *
$       ****************************************************************
$
PSHEAR  9999    99      0.01
$
$       ****************************************************************
$       *                     HORIZONTAL RODS                           *
$       ****************************************************************
$
$         TOP SURFACE:                          BOTTOM SURFACE:
CROD    301     121     1       3       302     121     2       4
CROD    303     122     3       5       304     122     4       6
CROD    305     123     5       7       306     123     6       8
CROD    307     124     7       9       308     124     8       10
CROD    309     124     9       11      310     124     10      12
CROD    311     123     11      25      312     123     12      26
CROD    313     117     13      1       314     118     14      2
CROD    315     110     15      3       316     103     16      4
CROD    317     110     17      5       318     103     18      6
CROD    319     110     19      7       320     103     20      8
CROD    321     110     21      9       322     103     22      10
CROD    323     110     23      11      324     103     24      12
CROD    325     134     13      15      326     127     14      16
CROD    327     135     15      17      328     128     16      18
CROD    329     135     17      19      330     128     18      20
CROD    331     136     19      21      332     129     20      22
CROD    333     136     21      23      334     129     22      24
CROD    335     135     23      25      336     128     24      26
CROD    337     122     25      27      338     122     26      28
CROD    339     121     27      29      340     121     28      30
CROD    341     120     29      31      342     120     30      32
CROD    343     119     33      13      344     118     34      14
CROD    345     111     35      15      346     104     36      16
CROD    347     111     37      17      348     104     38      18
```

```
PSHEAR  2222103 11       .406             3333103 21       .406
PSHEAR  2222104 11       .066             3333104 21       .066
PSHEAR  2222105 11       .080             3333105 21       .080
PSHEAR  2222106 11       .095             3333106 21       .095
PSHEAR  2222107 11       .140             3333107 21       .140
PSHEAR  2222201 12       .141             3333201 22       .141
PSHEAR  2222202 12       .406             3333202 22       .406
PSHEAR  2222203 12       .095             3333203 22       .095
PSHEAR  2222301 13       .219             3333301 23       .219
PSHEAR  2222302 13       .300             3333302 23       .300
PSHEAR  2222303 13       .212             3333303 23       .212
PSHEAR  2222304 13       .190             3333304 23       .190
PSHEAR  2222305 13       .182             3333305 23       .182
PSHEAR  2222401 14       .200             3333401 24       .200
PSHEAR  2222402 14       .246             3333402 24       .246
PSHEAR  2222403 14       .150             3333403 24       .150
PSHEAR  2222404 14       .411             3333404 24       .411
PSHEAR  2222405 14       .190             3333405 24       .190
PSHEAR  2222501 15       .371             3333501 25       .371
PSHEAR  2222502 15       .400             3333502 25       .400
PSHEAR  2222503 15       .204             3333503 25       .204
PSHEAR  2222504 15       .190             3333504 25       .190
PSHEAR  2222601 16       .320             3333601 26       .320
PSHEAR  2222602 16       .263             3333602 26       .263
PSHEAR  2222603 16       .300             3333603 26       .300
PSHEAR  2222701 17       .097             3333701 27       .097
PSHEAR  2222702 17       .065             3333702 27       .065
PSHEAR  2222801 18       .150             3333801 28       .150
PSHEAR  2222802 18       .400             3333802 28       .400
PSHEAR  2222803 18       .500             3333803 28       .500
$
$      ****************************************************************
$      *   PROPERTY CARDS FOR UNBUCKLED SKIN PANELS AWAY FROM DAMAGE   *
$      ****************************************************************
$
PSHEAR  1       1        .084             2       1        .081
PSHEAR  3       1        .128             4       1        .081
PSHEAR  5       1        .066             6       1        .05
PSHEAR  7       1        .14              8       1        .212
PSHEAR  9       1        .15              10      1        .411
PSHEAR  11      1        .204             12      1        .263
PSHEAR  13      1        .097             14      1        .182
PSHEAR  15      1        .1               16      1        .095
PSHEAR  17      1        .19              18      1        .3
PSHEAR  19      1        .065             20      1        .329
PSHEAR  21      1        .406             22      1        .141
PSHEAR  23      1        .219             24      1        .30
PSHEAR  25      1        .2               26      1        .246
PSHEAR  27      1        .371             28      1        .4
PSHEAR  29      1        .32              30      1        .5
PSHEAR  31      1        .15
$
$      ****************************************************************
$      * PROPERTY CARDS FOR UNBUCKLED SKIN PANELS ADJACENT TO DAMAGE   *
$      ****************************************************************
$
PSHEAR  11111   2        .084             11112   2        .081
PSHEAR  11113   2        .128             11114   2        .081
PSHEAR  11115   2        .066             11116   2        .05
PSHEAR  11117   2        .14              11118   2        .212
PSHEAR  11119   2        .15              111110  2        .411
PSHEAR  111111  2        .204             111112  2        .263
PSHEAR  111113  2        .097             111114  2        .182
PSHEAR  111115  2        .1               111116  2        .095
PSHEAR  111117  2        .19              111118  2        .3
PSHEAR  111119  2        .065             111120  2        .329
PSHEAR  111121  2        .406             111122  2        .141
PSHEAR  111123  2        .219             111124  2        .30
PSHEAR  111125  2        .2               111126  2        .246
PSHEAR  111127  2        .371             111128  2        .4
PSHEAR  111129  2        .32              111130  2        .5
PSHEAR  111131  2        .15
$
$      ****************************************************************
$      *    PROPERTY CARDS FOR BUCKLED SKIN PANELS AWAY FROM DAMAGE    *
$      ****************************************************************
$
PSHEAR  22221   3        .084             22222   3        .081
PSHEAR  22223   3        .128             22224   3        .081
PSHEAR  22225   3        .066             22226   3        .05
PSHEAR  22227   3        .14              22228   3        .212
PSHEAR  22229   3        .15              222210  3        .411
PSHEAR  222211  3        .204             222212  3        .263
PSHEAR  222213  3        .097             222214  3        .182
PSHEAR  222215  3        .1               222216  3        .095
PSHEAR  222217  3        .19              222218  3        .3
PSHEAR  222219  3        .065             222220  3        .329
PSHEAR  222221  3        .406             222222  3        .141
PSHEAR  222223  3        .219             222224  3        .30
PSHEAR  222225  3        .2               222226  3        .246
PSHEAR  222227  3        .371             222228  3        .4
PSHEAR  222229  3        .32              222230  3        .5
PSHEAR  222231  3        .15
PSHEAR  222251  5        .084             222252  5        .081
$
$      ****************************************************************
$      *   PROPERTY CARDS FOR BUCKLED SKIN PANELS ADJACENT TO DAMAGE   *
$      ****************************************************************
$
PSHEAR  33331   4        .084             33332   4        .081
PSHEAR  33333   4        .128             33334   4        .081
PSHEAR  33335   4        .066             33336   4        .05
PSHEAR  33337   4        .14              33338   4        .212
PSHEAR  33339   4        .15              333310  4        .411
PSHEAR  333311  4        .204             333312  4        .263
PSHEAR  333313  4        .097             333314  4        .182
PSHEAR  333315  4        .1               333316  4        .095
PSHEAR  333317  4        .19              333318  4        .3
PSHEAR  333319  4        .065             333320  4        .329
PSHEAR  333321  4        .406             333322  4        .141
PSHEAR  333323  4        .219             333324  4        .30
PSHEAR  333325  4        .2               333326  4        .246
PSHEAR  333327  4        .371             333328  4        .4
PSHEAR  333329  4        .32              333330  4        .5
PSHEAR  333331  4        .15
PSHEAR  333351  6        .084             333352  6        .081
$
$      ****************************************************************
$      *         PROPERTY CARDS FOR SKIN PANELS WHICH HAVE FAILED      *
$      ****************************************************************
$
PSHEAR  9999    99       0.01
$
$      ****************************************************************
$      *                      HORIZONTAL RODS                          *
$      ****************************************************************
$
$         TOP SURFACE:                          BOTTOM SURFACE:
CROD      301     121     1       3       302     121     2       4
CROD      303     122     3       5       304     122     4       6
CROD      305     123     5       7       306     123     6       8
CROD      307     124     7       9       308     124     8       10
CROD      309     124     9       11      310     124     10      12
CROD      311     123     11      25      312     123     12      26
CROD      313     117     13      1       314     118     14      2
CROD      315     110     15      3       316     103     16      4
CROD      317     110     17      5       318     103     18      6
CROD      319     110     19      7       320     103     20      8
CROD      321     110     21      9       322     103     22      10
CROD      323     110     23      11      324     103     24      12
CROD      325     124     13      15      326     127     14      16
CROD      327     126     15      17      328     128     16      18
CROD      329     126     17      19      330     126     18      20
CROD      331     130     19      21      332     129     20      22
CROD      333     130     21      23      334     129     22      24
CROD      335     126     23      25      336     128     24      26
CROD      337     122     25      27      338     122     26      28
CROD      339     121     27      29      340     121     28      30
CROD      341     120     29      31      342     120     30      32
CROD      343     119     33      13      344     118     34      14
CROD      345     111     35      15      346     104     36      16
CROD      347     111     37      17      348     104     38      18
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CROD    349     111     39      19      350     104     40      20
CROD    351     111     41      21      352     104     42      22
CROD    353     111     43      23      354     104     44      24
CROD    355     113     45      25      356     115     46      26
CROD    357     105     47      27      358     108     48      28
CROD    359     106     49      29      360     108     50      30
CROD    361     101     51      31      362     101     52      32
CROD    363     137     33      35      364     125     34      36
CROD    365     136     35      37      366     126     36      38
CROD    367     140     37      39      368     131     38      40
CROD    369     140     39      41      370     131     40      42
CROD    371     139     41      43      372     130     42      44
CROD    373     139     43      45      374     130     44      46
CROD    375     133     45      47      376     133     46      48
CROD    377     133     47      49      378     133     48      50
CROD    379     132     49      51      380     132     50      52
CROD    381     122     53      33      382     120     54      34
CROD    383     112     55      35      384     106     56      36
CROD    385     112     57      37      386     105     58      38
CROD    387     112     59      39      388     105     60      40
CROD    389     112     61      41      390     106     62      42
CROD    391     112     63      43      392     106     64      44
CROD    393     114     65      45      394     116     66      46
CROD    395     107     67      47      396     109     68      48
CROD    397     107     69      49      398     109     70      50
CROD    413     212     65      67      414     212     66      68
CROD    415     212     67      69      416     212     68      70
CROD    417     211     69      71      418     211     70      72
CROD    419     209     73      53      420     208     74      54
CROD    421     205     75      55      422     202     76      56
CROD    423     205     77      57      424     202     78      58
CROD    425     205     79      59      426     202     80      60
CROD    427     205     81      61      428     202     82      62
CROD    429     205     83      63      430     202     84      64
CROD    431     205     85      65      432     207     86      66
CROD    433     203     87      67      434     204     88      68
CROD    435     203     89      69      436     204     90      70
CROD    437     201     91      71      438     201     92      72
CROD    439     320     73      75      440     316     74      76
CROD    441     321     75      77      442     317     76      78
CROD    443     323     77      79      444     318     78      80
CROD    445     324     79      81      446     319     80      82
CROD    447     323     81      83      448     310     82      84
CROD    449     322     83      85      450     309     84      86
CROD    451     315     85      87      452     315     86      88
CROD    453     315     87      89      454     315     88      90
CROD    455     314     89      91      456     314     90      92
CROD    457     308     95      73      458     312     96      74
CROD    459     305     97      75      460     302     98      76
CROD    461     305     101     77      462     302     102     78
CROD    463     307     101     93      464     306     102     94
CROD    465     305     93      79      466     302     94      80
CROD    467     305     105     93
CROD    469     307     93      81      470     306     94      82
CROD    471     305     109     81
CROD    473     305     113     83
CROD    475     313     115     85      476     311     116     86
CROD    477     303     117     87      478     304     118     88
CROD    479     303     119     89      480     304     120     90
CROD    481     301     121     91      482     301     122     92
CROD    483     422     95      97      484     413     96      98
CROD    485     423     97      101     486     414     98      102
CROD    487     425     101     105     488     405     102     106
CROD    489     427     105     109     490     407     106     110
CROD    491     426     109     113     492     406     110     114
CROD    493     424     113     115     494     415     114     116
CROD    495     419     115     117     496     419     116     118
CROD    497     419     117     119     498     419     118     120
CROD    499     418     119     121     500     418     120     122
CROD    509     416     123     95      510     417     124     96
CROD    511     408     125     97
CROD    515     412     129     101
CROD    519     410     133     105
CROD    523     411     137     109
CROD    527     408     141     113     528     405     142     114
CROD    529     420     143     115     530     421     144     116
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CROD    531     403     145     117     532     404     146     118
CROD    533     403     147     119     534     404     148     120
CROD    535     401     149     121     536     401     150     122
CROD    537     508     123     125     538     506     124     126
CROD    539     510     125     129     540     507     126     130
CROD    543     512     129     133     544     508     130     134
CROD    547     515     133     137     548     505     134     138
CROD    551     512     137     141     552     508     138     142
CROD    555     511     141     143     556     514     142     144
CROD    557     519     143     145     558     519     144     146
CROD    559     519     145     147     560     519     146     148
CROD    561     518     147     149     562     518     148     150
CROD    563     516     151     123     564     517     152     124
CROD    565     504     153     125     566     503     154     126
CROD    567     504     155     129     568     503     156     130
CROD    569     504     157     133     570     503     158     134
CROD    571     504     159     137     572     503     160     138
CROD    573     504     161     141     574     503     162     142
CROD    575     514     163     143     576     513     164     144
CROD    577     502     165     145     578     502     166     146
CROD    579     502     167     147     580     502     168     148
CROD    581     501     169     149     582     501     170     150
CROD    583     607     151     153     584     605     152     154
CROD    585     611     153     155     586     606     154     156
CROD    587     612     155     157     588     608     156     158
CROD    589     614     157     159     590     610     158     160
CROD    591     613     159     161     592     609     160     162
CROD    593     612     161     163     594     607     162     164
CROD    595     616     163     165     596     618     164     166
CROD    597     616     165     167     598     618     166     168
CROD    599     615     167     169     600     615     168     170
CROD    601     805     171     151     602     806     172     152
CROD    603     604     173     153     604     603     174     154
CROD    605     604     175     155     606     603     176     156
CROD    607     604     177     157     608     603     178     158
CROD    609     604     179     159     610     603     180     160
CROD    611     604     181     161     612     603     182     162
CROD    613     617     183     163     614     618     184     164
CROD    615     602     185     165     616     602     186     166
CROD    617     602     187     167     618     602     188     168
CROD    619     601     189     169     620     601     190     170
CROD    621     703     171     173     622     701     172     174
CROD    623     705     173     175     624     702     174     176
CROD    625     706     175     177     626     703     176     178
CROD    627     706     177     179     628     704     178     180
CROD    629     706     179     181     630     704     180     182
CROD    631     706     181     183     632     704     182     184
CROD    633     709     183     185     634     709     184     186
CROD    635     708     185     187     636     708     186     188
CROD    637     707     187     189     638     707     188     190
CROD    639     803     191     171     640     804     192     172
CROD    641     808     193     183     642     807     194     184
CROD    399     102     71      51      400     102     72      52
CROD    401     210     53      55      402     210     54      56
CROD    403     210     55      57      404     210     56      58
CROD    405     210     57      59      406     210     58      60
CROD    407     210     59      61      408     210     60      62
CROD    409     210     61      63      410     210     62      64
CROD    411     210     63      65      412     210     64      66
CROD    711     802     123     151     712     801     124     152
$
$       *************************************************************
$       *                      VERTICAL RODS                        *
$       *************************************************************
$
CROD    650     5       57      58
CROD    651     5       59      60
CROD    652     5       61      62
CROD    653     5       63      64
CROD    1101    1       1       2       1102    1       3       4
CROD    1103    1       5       6       1104    1       7       8
CROD    1105    1       9       10      1106    1       11      12
CROD    1107    1       13      14      1108    1       15      16
CROD    1109    1       17      18      1110    1       19      20
CROD    1111    1       21      22      1112    1       23      24
CROD    1113    1       25      26      1114    1       27      28
```

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CROD    1115    1       29      30      1116    42      31      32
CROD    1117    1       33      34      1118    1       35      36
CROD    1119    1       37      38      1120    1       39      40
CROD    1121    1       41      42      1122    1       43      44
CROD    1123    1       45      46      1124    1       47      48
CROD    1125    1       49      50      1126    67      51      52
CROD    1127    1       53      54      1128    1       55      56
CROD    1129    1       65      66      1130    1       67      68
CROD    1131    1       69      70      1132    73      71      72
CROD    1133    1       73      74      1134    1       75      76
CROD    1135    1       77      78      1136    1       79      80
CROD    1137    1       81      82      1138    1       83      84
CROD    1139    1       85      86      1140    1       87      88
CROD    1141    1       89      90      1142    9       91      92
CROD    1143    1       93      94      1144    1       95      96
CROD    1145    1       97      98
CROD    1147    1       101     102
CROD    1149    1       105     106
CROD    1151    1       109     110
CROD    1153    1       113     114     1154    1       115     116
CROD    1155    1       117     118     1156    1       119     120
CROD    1157    97      121     122     1158    1       123     124
CROD    1159    1       125     126
CROD    1161    1       129     130
CROD    1163    1       133     134
CROD    1165    1       137     138
CROD    1167    1       141     142
CROD    1169    1       145     146     1170    1       147     148
CROD    1171    98      149     150     1172    1       151     152
CROD    1173    1       153     154     1174    1       155     156
CROD    1175    1       157     158     1176    1       159     160
CROD    1177    1       161     162
CROD    1179    1       165     166     1180    1       167     168
CROD    1181    99      169     170     1182    1       171     172
CROD    1183    1       173     174     1184    1       175     176
CROD    1185    1       177     178     1186    1       179     180
CROD    1187    1       181     182     1188    1       183     184
CROD    1189    1       185     186     1190    1       187     188
CROD    1191    98      189     190
CROD    1268    1       143     144
CROD    1278    1       163     164
$
$       ***********************************************************
$       *       PROPERTY CARDS FOR ROD ELEMENTS AWAY FROM DAMAGE   *
$       ***********************************************************
$
PROD    1       11      0.001
PROD    5       11      0.20
PROD    9       11      0.33
PROD    42      11      1.03
PROD    67      11      1.68
PROD    73      11      1.78
PROD    96      11      2.67
PROD    97      11      3.19
PROD    98      11      5.40
PROD    99      11      5.80
PROD    101     11      0.15
PROD    102     11      0.18
PROD    103     11      0.33
PROD    104     11      0.52
PROD    105     11      0.56
PROD    106     11      0.58
PROD    107     11      0.61
PROD    108     11      0.66
PROD    109     11      0.68
PROD    110     11      0.70
PROD    111     11      0.72
PROD    112     11      0.75
PROD    113     11      0.79
PROD    114     11      0.80
PROD    115     11      0.82
PROD    116     11      0.84
PROD    117     11      0.96
PROD    118     11      0.97
PROD    119     11      1.00
PROD    120     11      1.03
PROD    121     11      1.04
PROD    122     11      1.05
PROD    123     11      1.06
PROD    124     11      1.07
PROD    125     11      1.33
PROD    126     11      1.37
PROD    127     11      1.38
PROD    128     11      1.40
PROD    129     11      1.41
PROD    130     11      1.49
PROD    131     11      1.50
PROD    132     11      1.68
PROD    133     11      1.69
PROD    134     11      1.73
PROD    135     11      1.74
PROD    136     11      1.75
PROD    137     11      1.89
PROD    138     11      1.92
PROD    139     11      1.94
PROD    140     11      1.95
PROD    201     12      0.29
PROD    202     12      0.57
PROD    203     12      0.63
PROD    204     12      0.70
PROD    205     12      0.77
PROD    206     12      0.83
PROD    207     12      0.85
PROD    208     12      1.07
PROD    209     12      1.09
PROD    210     12      1.70
PROD    211     12      1.78
PROD    212     12      1.79
PROD    301     13      0.26
PROD    302     13      0.62
PROD    303     13      0.76
PROD    304     13      0.83
PROD    305     13      0.88
PROD    306     13      1.02
PROD    307     13      1.18
PROD    308     13      1.49
PROD    309     13      1.65
PROD    310     13      1.67
PROD    311     13      1.89
PROD    312     13      1.96
PROD    313     13      2.17
PROD    314     13      2.57
PROD    315     13      2.58
PROD    316     13      3.20
PROD    317     13      3.23
PROD    318     13      3.26
PROD    319     13      3.27
PROD    320     13      3.36
PROD    321     13      3.38
PROD    322     13      3.40
PROD    323     13      3.41
PROD    324     13      3.42
PROD    401     14      0.28
PROD    402     14      0.48
PROD    403     14      0.81
PROD    404     14      0.88
PROD    405     14      0.97
PROD    406     14      1.02
PROD    407     14      1.30
PROD    408     14      1.37
PROD    409     14      1.50
PROD    410     14      1.63
PROD    411     14      1.70
PROD    412     14      1.84
PROD    413     14      2.00
PROD    414     14      2.02
PROD    415     14      2.31
PROD    416     14      2.40
PROD    417     14      2.86
PROD    418     14      3.19
PROD    419     14      3.20
PROD    420     14      3.23
```

```
PROD    421     14      3.42
PROD    422     14      4.02
PROD    423     14      4.04
PROD    424     14      4.08
PROD    425     14      4.22
PROD    426     14      4.23
PROD    427     14      4.37
PROD    501     15      0.15
PROD    502     15      0.38
PROD    503     15      0.82
PROD    504     15      0.96
PROD    505     15      2.00
PROD    506     15      2.04
PROD    507     15      2.08
PROD    508     15      2.10
PROD    509     15      3.88
PROD    510     15      3.82
PROD    511     15      3.83
PROD    512     15      3.84
PROD    513     15      3.80
PROD    514     15      3.87
PROD    515     15      4.08
PROD    516     15      4.10
PROD    517     15      4.35
PROD    518     15      4.42
PROD    519     15      4.43
PROD    601     16      0.28
PROD    602     16      0.71
PROD    603     16      0.82
PROD    604     16      1.02
PROD    605     16      3.08
PROD    606     16      3.10
PROD    607     16      3.13
PROD    608     16      3.14
PROD    609     16      3.15
PROD    610     16      3.17
PROD    611     16      3.18
PROD    612     16      3.21
PROD    613     16      3.22
PROD    614     16      3.23
PROD    615     16      4.00
PROD    616     16      4.02
PROD    617     16      6.23
PROD    618     16      7.01
PROD    701     17      1.29
PROD    702     17      1.30
PROD    703     17      1.31
PROD    704     17      1.32
PROD    705     17      1.33
PROD    706     17      1.34
PROD    707     17      1.70
PROD    708     17      1.88
PROD    709     17      1.92
PROD    801     18      0.68
PROD    802     18      0.73
PROD    803     18      2.84
PROD    804     18      3.04
PROD    805     18      4.10
PROD    806     18      4.38
PROD    807     18      4.84
PROD    808     18      5.02
$
$      ***************************************************************
$      *       PROPERTY CARDS FOR ROD ELEMENTS ADJACENT TO DAMAGE    *
$      ***************************************************************
$
PROD    88881   11      0.001
PROD    88886   11      0.20
PROD    88888   11      0.33
PROD    888842  11      1.03
PROD    888867  11      1.08
PROD    888873  11      1.78
PROD    888886  11      2.67
PROD    888887  11      3.19
PROD    888888  11      5.40
PROD    888889  11      5.80
PROD    8888101 21      0.15
PROD    8888102 21      0.18
PROD    8888103 21      0.33
PROD    8888104 21      0.52
PROD    8888105 21      0.55
PROD    8888106 21      0.58
PROD    8888107 21      0.61
PROD    8888108 21      0.66
PROD    8888109 21      0.69
PROD    8888110 21      0.70
PROD    8888111 21      0.72
PROD    8888112 21      0.75
PROD    8888113 21      0.79
PROD    8888114 21      0.80
PROD    8888115 21      0.82
PROD    8888116 21      0.84
PROD    8888117 21      0.96
PROD    8888118 21      0.97
PROD    8888119 21      1.00
PROD    8888120 21      1.03
PROD    8888121 21      1.04
PROD    8888122 21      1.06
PROD    8888123 21      1.06
PROD    8888124 21      1.07
PROD    8888125 21      1.33
PROD    8888126 21      1.37
PROD    8888127 21      1.39
PROD    8888128 21      1.40
PROD    8888129 21      1.41
PROD    8888130 21      1.49
PROD    8888131 21      1.50
PROD    8888132 21      1.68
PROD    8888133 21      1.69
PROD    8888134 21      1.73
PROD    8888135 21      1.74
PROD    8888136 21      1.75
PROD    8888137 21      1.89
PROD    8888138 21      1.92
PROD    8888139 21      1.94
PROD    8888140 21      1.95
PROD    8888201 22      0.29
PROD    8888202 22      0.57
PROD    8888203 22      0.63
PROD    8888204 22      0.70
PROD    8888205 22      0.77
PROD    8888206 22      0.83
PROD    8888207 22      0.85
PROD    8888208 22      1.07
PROD    8888209 22      1.09
PROD    8888210 22      1.70
PROD    8888211 22      1.78
PROD    8888212 22      1.79
PROD    8888301 23      0.26
PROD    8888302 23      0.62
PROD    8888303 23      0.76
PROD    8888304 23      0.83
PROD    8888305 23      0.88
PROD    8888306 23      1.02
PROD    8888307 23      1.18
PROD    8888308 23      1.49
PROD    8888309 23      1.65
PROD    8888310 23      1.67
PROD    8888311 23      1.89
PROD    8888312 23      1.96
PROD    8888313 23      2.17
PROD    8888314 23      2.57
PROD    8888315 23      2.58
PROD    8888316 23      3.20
PROD    8888317 23      3.23
PROD    8888318 23      3.26
PROD    8888319 23      3.27
PROD    8888320 23      3.36
PROD    8888321 23      3.38
PROD    8888322 23      3.40
PROD    8888323 23      3.41
PROD    8888324 23      3.42
```

```
PROD    8888401 24      0.28
PROD    8888402 24      0.46
PROD    8888403 24      0.61
PROD    8888404 24      0.88
PROD    8888405 24      0.97
PROD    8888406 24      1.02
PROD    8888407 24      1.30
PROD    8888408 24      1.37
PROD    8888409 24      1.50
PROD    8888410 24      1.63
PROD    8888411 24      1.70
PROD    8888412 24      1.84
PROD    8888413 24      2.00
PROD    8888414 24      2.02
PROD    8888415 24      2.31
PROD    8888416 24      2.90
PROD    8888417 24      2.86
PROD    8888418 24      3.19
PROD    8888419 24      3.20
PROD    8888420 24      3.23
PROD    8888421 24      3.42
PROD    8888422 24      4.02
PROD    8888423 24      4.04
PROD    8888424 24      4.08
PROD    8888425 24      4.22
PROD    8888426 24      4.23
PROD    8888427 24      4.37
PROD    8888501 25      0.15
PROD    8888502 25      0.38
PROD    8888503 25      0.82
PROD    8888504 25      0.96
PROD    8888505 25      2.00
PROD    8888506 25      2.04
PROD    8888507 25      2.08
PROD    8888508 25      2.10
PROD    8888509 25      3.58
PROD    8888510 25      3.62
PROD    8888511 25      3.63
PROD    8888512 25      3.64
PROD    8888513 25      3.80
PROD    8888514 25      3.97
PROD    8888515 25      4.06
PROD    8888516 25      4.10
PROD    8888517 25      4.35
PROD    8888518 25      4.42
PROD    8888519 25      4.43
PROD    8888601 26      0.28
PROD    8888602 26      0.71
PROD    8888603 26      0.82
PROD    8888604 26      1.02
PROD    8888605 26      3.06
PROD    8888606 26      3.10
PROD    8888607 26      3.13
PROD    8888608 26      3.14
PROD    8888609 26      3.15
PROD    8888610 26      3.17
PROD    8888611 26      3.18
PROD    8888612 26      3.21
PROD    8888613 26      3.22
PROD    8888614 26      3.23
PROD    8888615 26      4.00
PROD    8888616 26      4.02
PROD    8888617 26      6.23
PROD    8888618 26      7.01
PROD    8888701 27      1.29
PROD    8888702 27      1.30
PROD    8888703 27      1.31
PROD    8888704 27      1.32
PROD    8888705 27      1.33
PROD    8888706 27      1.34
PROD    8888707 27      1.70
PROD    8888708 27      1.88
PROD    8888709 27      1.92
PROD    8888801 28      0.69
PROD    8888802 28      0.73
PROD    8888803 28      2.84
PROD    8888804 28      3.04
PROD    8888805 28      4.10
PROD    8888806 28      4.35
PROD    8888807 28      4.64
PROD    8888808 28      5.02
$
$       ***************************************************************
$       *       PROPERTY CARDS FOR ROD ELEMENTS WHICH HAVE FAILED     *
$       ***************************************************************
$
PROD    9999    99      0.01
$
$       ***************************************************************
$       *                      ELASTIC SPRINGS                        *
$       ***************************************************************
$
CELAS2  9490    7.633+3 102     1       106     1
CELAS2  9494    1.1+4   106     1       110     1
CELAS2  9498    7.633+3 110     1       114     1
$
$       ***************************************************************
$       *                     TRIANGULAR MEMBERS                      *
$       ***************************************************************
$
CTRMEM  275     222251  23      11      25
CTRMEM  276     222251  24      12      26
CTRMEM  277     222252  93      79      81
CTRMEM  278     222252  94      80      82
CTRMEM  279     222252  101     93      105
PTRMEM  1       1       0.064           2       1       0.081
PTRMEM  11111   2       0.064           11112   2       0.081
PTRMEM  22221   3       0.064           22222   3       0.081
PTRMEM  33331   4       0.064           33332   4       0.081
PTRMEM  222251  5       0.064           222252  5       0.081
PTRMEM  333351  6       0.064           333352  6       0.081
PTRMEM  9999    99      0.01
$
$       ***************************************************************
$       *                 SINGLE POINT CONSTRAINTS                    *
$       ***************************************************************
$
SPC     100     191     1       0.0     191     2       0.0
SPC     100     192     1       0.0     192     2       0.0
SPC     100     193     1       0.0     193     2       0.0
SPC     100     194     1       0.0     194     2       0.0
SPC     100     191     3               192     3
SPC     100     193     3               194     3
$       ***************************************************************
$       SPC ID NUMBERS ARE THE APPLIED LOAD IN KIPS
$       SPC VALUES SHOWN ARE FOR TEST 3A
SPC     2       191     1       +.020   191     2       0.000
SPC     2       191     3       -.035   192     3       -.035
SPC     2       192     1       -.020   192     2       0.000
SPC     2       193     1       +.040   193     2       0.000
SPC     2       193     3       -.005   194     3       -.005
SPC     2       194     1       -.040   194     2       0.000
SPC     4       191     1       +.046   191     2       0.000
SPC     4       191     3       -.070   192     3       -.070
SPC     4       192     1       -.046   192     2       0.000
SPC     4       193     1       +.080   193     2       0.000
SPC     4       193     3       -.025   194     3       -.025
SPC     4       194     1       -.080   194     2       0.000
SPC     6       191     1       +.058   191     2       0.000
SPC     6       191     3       -.130   192     3       -.130
SPC     6       192     1       -.058   192     2       0.000
SPC     6       193     1       +.066   193     2       0.000
SPC     6       193     3       -.035   194     3       -.035
SPC     6       194     1       -.066   194     2       0.000
SPC     8       191     1       +.067   191     2       0.000
SPC     8       191     3       -.145   192     3       -.145
SPC     8       192     1       -.067   192     2       0.000
SPC     8       193     1       +.071   193     2       0.000
SPC     8       193     3       -.040   194     3       -.040
SPC     8       194     1       -.071   194     2       0.000
SPC     10      191     1       +.074   191     2       0.000
SPC     10      191     3       -.165   192     3       -.165
```

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SPC     10      192     1       -.074   192     2       0.000
SPC     10      193     1       +.078   193     2       0.000
SPC     10      193     3       -.040   194     3       -.040
SPC     10      194     1       -.076   194     2       0.000
SPC     12      191     1       +.079   191     2       0.000
SPC     12      191     3       -.170   192     3       -.170
SPC     12      192     1       -.079   192     2       0.000
SPC     12      193     1       +.080   193     2       0.000
SPC     12      193     3       -.045   194     3       -.045
SPC     12      194     1       -.080   194     2       0.000
$
$       ****************************************************************
$       *                   MULTIPOINT CONSTRAINTS                     *
$       ****************************************************************
$
MPC     100     184     1       .34     184     1       -1.0
MPC     100     164     2       .33     184     2       -1.0
MPC     100     163     1       .36     183     1       -1.0
MPC     100     163     2       .34     183     2       -1.0
MPC     100     152     1       .76     172     1       -1.0
MPC     100     151     1       .76     171     1       -1.0
MPC     100     152     2       .8      172     2       -1.0
MPC     100     151     2       .8      171     2       -1.0
MPC     100     96      2       -1.0    74      2       .53     +MPC1
+MPC1           152     2       .47
MPC     100     124     2       -1.0    74      2       .11     +MPC2
+MPC2           152     2       .89
MPC     100     84      1       .48     142     1       .52     +MPC3
+MPC3           114     1       -1.
MPC     100     78      1       .48     130     1       .52     +MPC4
+MPC4           102     1       -1.0
MPC     100     76      1       .48     126     1       .52     +MPC5
+MPC5           98      1       -1.0
MPC     100     82      1       .48     138     1       .52     +MPC6
+MPC6           110     1       -1.0
MPC     100     94      1       .66     134     1       .34     +MPC7
$       ****************************************************************
$       *     MATERIAL CARDS FOR SPARS AND RIBS AWAY FROM DAMAGE       *
$       ****************************************************************
$
MAT1    11      10.3+6  3.9+6           3.14-3                  +M11
+M11    3.75+4  3.75+4  3.83+4
MAT1    12      10.3+6  3.9+6           3.14-3                  +M12
+M12    5.51+4  5.51+4  3.83+4
MAT1    13      10.3+6  3.9+6           3.14-3                  +M13
+M13    5.91+4  5.91+4  3.83+4
MAT1    14      10.3+6  3.9+6           3.14-3                  +M14
+M14    6.41+4  6.41+4  3.83+4
MAT1    15      10.3+6  3.9+6           3.14-3                  +M15
+M15    6.91+4  6.91+4  3.83+4
MAT1    16      10.3+6  3.9+6           3.14-3                  +M16
+M16    7.03+4  7.03+4  3.83+4
MAT1    17      10.3+6  3.9+6           3.14-3                  +M17
+M17    7.27+4  7.27+4  3.83+4
MAT1    18      30.0+6  11.0+6          8.73-3                  +M18
+M18    22.8+4  22.8+4  12.33+4
$     MATERIALS 11 THRU 17 ARE FOR ALUMINUM 1-D AND 2-D
$      ELEMENTS AWAY FROM DAMAGE. BASIC LIMITING
$      STRESSES ARE: T&C= 7.9+4 AND S= 4.9+4.
$      THE BASIC LIMITING STRESSES FOR T&C ARE FACTORED
$      AS FOLLOWS USING FORMAT (MID:FACTOR)
$      (11:.5000) (12:.7350) (13:.7882) (14:.8547)
$      (15:.9210) (16:.9380) (17:.9687)
$
$     MATERIAL 18 IS FOR STEEL 1-D AND 2-D ELEMENTS AWAY
$     WITH LIMITING STRESSES T&C= 240+3 AND S= 140+3.
$     THE FACTOR FOR T&C IS (18:.9500)
$
$     THE FACTOR FOR S FOR ALL MID NUMBERS IS 0.8900
$
$       ****************************************************************
$       *    MATERIAL CARDS FOR SPARS AND RIBS BORDERING DAMAGE        *
$       ****************************************************************
$
MAT1    21      10.3+6  3.9+6           3.14-3                  +M21
+M21    1.80+4  3.75+4  2.77+4
MAT1    22      10.3+6  3.9+6           3.14-3                  +M22
+M22    2.64+4  5.51+4  2.77+4
MAT1    23      10.3+6  3.9+6           3.14-3                  +M23
+M23    2.84+4  5.91+4  2.77+4
MAT1    24      10.3+6  3.9+6           3.14-3                  +M24
+M24    3.08+4  6.41+4  2.77+4
MAT1    25      10.3+6  3.9+6           3.14-3                  +M25
+M25    3.32+4  6.91+4  2.77+4
MAT1    26      10.3+6  3.9+6           3.14-3                  +M26
+M26    3.37+4  7.03+4  2.77+4
MAT1    27      10.3+6  3.9+6           3.14-3                  +M27
+M27    3.49+4  7.27+4  2.77+4
MAT1    28      30.0+6  11.0+6          8.73-3                  +M28
+M28    10.9+4  22.8+4  8.94+4
$
$     MATERIALS 21 THRU 28 ARE FOR 1-D AND 2-D ELEMENTS
$      BORDERING DAMAGE AND CORRESPOND TO MATERIALS 11 THRU 18
$      RESPECTIVELY.  PREVIOUS LIMITING STRESSES ARE FURTHER
$      FACTORED AS FOLLOWS:  (T:.480) (C:1.00) (S:.725)
$
$       ****************************************************************
$       *            MATERIAL CARDS FOR SKIN PANEL ELEMENTS            *
$       ****************************************************************
$
MAT1    1       10.3+6  3.9+6           3.14-3                  +M1
+M1     4.24+4  1.28+4  1.49+4
MAT1    2       10.3+6  3.9+6           3.14-3                  +M2
+M2     4.24+4  1.28+4  1.49+4
MAT1    3       7.79+6  2.05+6          3.14-3                  +M3
+M3     7.70+4  7.70+4  4.60+4
MAT1    4       7.79+6  2.05+6          3.14-3                  +M4
+M4     3.67+4  7.70+4  3.34+4
$
$     MATERIALS 1 THRU 4 ARE FOR ALUMINUM SKIN PANELS.
$      THEY ARE FOR:  1 - UNBUCKLED AWAY FROM DAMAGE
$                     2 - UNBUCKLED BORDERING DAMAGE
$                     3 - BUCKLED AWAY FROM DAMAGE
$                     4 - BUCKLED BORDERING DAMAGE
$      BASIC LIMITING STRESSES ARE:  T&C=7.7+4  AND  S=4.6+4
$      THE BASIC LIMITING STRESSES ARE FACTORED AS FOLLOWS
$      USING FORMAT (MID:TYPE STRESS:FACTOR)
$      (1:T:.5500) (1:C:.1667) (1:S:.3241)
$      (2:T:.5500) (2:C:.1667) (2:S:.3241)
$      (3:T:1.000) (3:C:1.000) (3:S:1.000)
$      (4:T:.4770) (4:C:1.000) (4:S:.7250)
$      POST-BUCKLING MODULUS REDUCTION FACTORS ARE:
$      (E:.7564) (G:.5254)
$
$
MAT1    5       10.3+6  3.9+6           3.14-3                  +M5
+M5     7.70+4  7.70+4  4.60+4
MAT1    6       10.3+6  3.9+6           3.14-3                  +M6
+M6     3.67+4  7.70+4  3.34+4
$
$     MATERIALS 5 AND 6 ARE FOR ALUMINUM SKIN PANELS BORDERING SPARS.
$      AWAY FROM DAMAGE AND BORDERING DAMAGE RESPECTIVELY.  NO
$      BUCKLING AND ORIGINAL STIFFNESSES ARE ASSUMED.  GENERAL
$      SKIN PANEL POST-BUCKLING LIMITING STRESSES ARE USED.
$
$       ****************************************************************
$       *     SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE   *
$       ****************************************************************
$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    99.9+9  99.9+9  99.9+9
$
$       ****************************************************************
$       *                    MISCELLANEOUS CARDS                       *
$       ****************************************************************
$
GRDSET                                          456
PARAM   GRDPNT  0
```

```
$       ********************************************************************
$       *                          APPLIED FORCES                          *
$       ********************************************************************
$
GRAV    3       0       386.4   0.0     0.0     -1.0
FORCE   1       33              500.    0.0     0.0     1.0
FORCE   1       34              500.    0.0     0.0     1.0
FORCE   2       45              500.    0.0     0.0     1.0
FORCE   2       46              500.    0.0     0.0     1.0
$     NET LOADING CONDITIONS
LOAD    101     1.0     1.0     1
LOAD    102     1.0     2.0     1
LOAD    103     1.0     3.0     1
LOAD    104     1.0     4.0     1
LOAD    105     1.0     5.0     1
LOAD    106     1.0     6.0     1
LOAD    107     1.0     7.0     1
LOAD    108     1.0     8.0     1
LOAD    109     1.0     9.0     1
LOAD    110     1.0     10.0    1
LOAD    111     1.0     11.0    1
LOAD    112     1.0     12.0    1
LOAD    113     1.0     13.0    1
LOAD    114     1.0     14.0    1
LOAD    115     1.0     15.0    1
LOAD    116     1.0     16.0    1
LOAD    117     1.0     17.0    1
LOAD    118     1.0     18.0    1
LOAD    119     1.0     19.0    1
LOAD    120     1.0     20.0    1
LOAD    121     1.0     21.0    1
LOAD    122     1.0     22.0    1
LOAD    123     1.0     23.0    1
LOAD    124     1.0     24.0    1
LOAD    125     1.0     25.0    1
LOAD    126     1.0     26.0    1
LOAD    127     1.0     27.0    1
LOAD    128     1.0     28.0    1
LOAD    131     1.0     31.0    1
LOAD    132     1.0     32.0    1
LOAD    133     1.0     33.0    1
LOAD    134     1.0     34.0    1
LOAD    135     1.0     35.0    1
LOAD    136     1.0     36.0    1
LOAD    137     1.0     37.0    1
LOAD    138     1.0     38.0    1
LOAD    139     1.0     39.0    1
LOAD    140     1.0     40.0    1
LOAD    141     1.0     41.0    1
LOAD    142     1.0     42.0    1
LOAD    143     1.0     43.0    1
LOAD    144     1.0     44.0    1
LOAD    145     1.0     45.0    1
$     GROSS LOADING CONDITIONS
LOAD    200     1.0     1.0     3
LOAD    201     1.0     1.0     1               1.0     3
LOAD    202     1.0     2.0     1               1.0     3
LOAD    203     1.0     3.0     1               1.0     3
LOAD    204     1.0     4.0     1               1.0     3
LOAD    205     1.0     5.0     1               1.0     3
LOAD    206     1.0     6.0     1               1.0     3
LOAD    207     1.0     7.0     1               1.0     3
LOAD    208     1.0     8.0     1               1.0     3
LOAD    209     1.0     9.0     1               1.0     3
LOAD    210     1.0     10.0    1               1.0     3
LOAD    211     1.0     11.0    1               1.0     3
LOAD    212     1.0     12.0    1               1.0     3
LOAD    213     1.0     13.0    1               1.0     3
LOAD    214     1.0     14.0    1               1.0     3
LOAD    215     1.0     15.0    1               1.0     3
LOAD    216     1.0     16.0    1               1.0     3
$
ENDDATA
```

APPENDIX E

FINITE ELEMENT MODEL C LISTING

```
$       ***************************************************************
$       *                    BULK DATA DECK FOR                      *
$       *          F-84F WING PROJECT - UNDAMAGED WING               *
$       *                MODEL C - STATIC CASE                       *
$       *             SPARS AND RIBS:  CROD AND CSHEAR               *
$       *                 STIFFENERS:  CROD                          *
$       *                SKIN PANELS:  CQDMEM                        *
$       *          NO TORSIONAL STIFFNESS IN SPARS                   *
$       ***************************************************************
$
$       THE WING ALUMINUM IS 7075-T6 EXCEPT 2024-T3 IN A FEW SKIN PANELS
$       THE WING SPAR ROOTS ARE 5 CR-MO-V AIRCRAFT STEEL
$
$       ***************************************************************
$       *                 GRID POINTS - TOP OF WING                   *
$       ***************************************************************
$
GRID    1               232.9   -30.4   -2.8
GRID    3               229.    -25.33  -2.9
GRID    5               225.    -20.27  -3.2
GRID    7               221.    -15.2   -3.5
GRID    9               217.    -10.13  -3.55
GRID    11              213.    -5.07   -3.45
GRID    13              209.    -32.5   -2.65
GRID    15              209.    -27.08  -3.05
GRID    17              209.    -21.67  -3.3
GRID    19              209.    -16.25  -3.55
GRID    21              209.    -10.83  -3.55
GRID    23              209.    -5.47   -3.5
GRID    25              209.    0.0     -3.25
GRID    27              203.9   6.4     -2.6
GRID    29              199.9   11.7    -1.05
GRID    31              196.8   15.6    -.5
GRID    33              184.1   -34.7   -2.85
GRID    35              184.1   -28.92  -3.25
GRID    37              184.1   -23.13  -3.65
GRID    39              184.1   -17.35  -3.9
GRID    41              184.1   -11.57  -3.8
GRID    43              184.1   -5.78   -3.65
GRID    45              184.1   0.0     -3.5
GRID    47              184.1   6.7     -2.65
GRID    49              184.1   12.1    -1.9
GRID    51              184.1   16.0    -.5
GRID    53              159.1   -36.85  -3.05
GRID    55              159.1   -30.71  -3.45
GRID    57              159.1   -24.57  -3.85
GRID    59              159.1   -18.425 -4.1
GRID    61              159.1   -12.28  -4.05
GRID    63              159.1   -6.14   -3.9
GRID    65              159.1   0.0     -3.7
GRID    67              159.1   7.0     -2.8
GRID    69              159.1   12.7    -2.
GRID    71              159.1   17.1    -.5
GRID    73              134.4   -39.    -3.3
GRID    75              133.82  -32.5   -3.7
GRID    77              133.23  -26.    -4.1
GRID    79              132.65  -19.5   -4.35
GRID    81              132.07  -13.    -4.35
GRID    83              131.48  -6.5    -4.2
GRID    85              130.9   0.0     -4.
GRID    87              130.9   7.4     -3.0
GRID    89              130.9   13.4    -2.1
GRID    91              130.9   18.3    -.5
GRID    93              111.35  -20.43  -4.58
GRID    95              91.8    -42.7   -3.6
GRID    97              91.8    -35.58  -4.
GRID    101             91.8    -28.47  -4.35
GRID    105             91.8    -21.35  -4.6
GRID    109             91.8    -14.23  -4.75
GRID    113             91.8    -7.12   -4.5
GRID    115             91.8    0.0     -4.35
GRID    117             91.8    8.0     -3.3
GRID    119             91.8    14.4    -2.25
GRID    121             91.8    20.     -.5
GRID    123             54.     -48.3   -4.
GRID    125             54.     -38.58  -4.35
GRID    129             54.     -30.87  -4.85
GRID    133             54.     -23.15  -5.15
GRID    137             54.     -15.43  -5.1
GRID    141             54.     -7.72   -4.85
GRID    143             54.     0.0     -4.7
GRID    145             54.     8.5     -3.55
GRID    147             54.     15.4    -2.4
GRID    149             54.     21.6    -.5
GRID    151             43.8    -47.2   -4.
GRID    153             41.43   -39.33  -4.5
GRID    155             39.07   -31.47  -4.95
GRID    157             36.7    -23.6   -5.25
GRID    159             34.33   -15.73  -5.35
GRID    161             31.97   -7.87   -5.1
GRID    163             29.6    0.0     -5.
GRID    165             27.3    7.7     -4.
GRID    167             25.     15.3    -2.8
GRID    169             22.7    23.     -.5
GRID    171             41.1    -49.    -4.
GRID    173             36.28   -43.27  -4.3
GRID    175             31.47   -37.53  -4.75
GRID    177             26.65   -31.8   -5.15
GRID    179             21.83   -26.07  -5.4
GRID    181             17.02   -20.33  -5.45
GRID    183             12.7    -14.6   -5.45
GRID    185             .5      -.5     -5.
GRID    187             -10.    11.5    -3.6
GRID    189             -21.5   24.6    -.5
GRID    191             32.7    -56.1   -3.95
GRID    193             3.3     -22.1   -5.
$
$       ***************************************************************
$       *               GRID POINTS - BOTTOM OF WING                  *
$       ***************************************************************
$
GRID    2               232.9   -30.4   2.8
GRID    4               229.    -25.33  2.9
GRID    6               225.    -20.27  3.2
GRID    8               221.    -15.2   3.5
GRID    10              217.    -10.13  3.55
GRID    12              213.    -5.07   3.45
GRID    14              209.    -32.5   2.65
GRID    16              209.    -27.08  3.05
GRID    18              209.    -21.67  3.3
GRID    20              209.    -16.25  3.55
GRID    22              209.    -10.83  3.55
GRID    24              209.    -5.42   3.5
GRID    26              209.    0.0     3.25
GRID    28              204.3   6.0     2.6
GRID    30              199.2   12.6    1.05
GRID    32              196.8   15.6    .5
GRID    34              184.1   -34.7   2.85
GRID    36              184.1   -28.92  3.25
GRID    38              184.1   -23.13  3.65
GRID    40              184.1   -17.35  3.9
GRID    42              184.1   -11.57  3.8
GRID    44              184.1   -5.78   3.65
GRID    46              184.1   0.0     3.5
GRID    48              184.1   6.2     2.65
GRID    50              184.1   13.0    1.9
GRID    52              184.1   16.0    .5
GRID    54              159.1   -36.85  3.05
GRID    56              159.1   -30.71  3.45
GRID    58              159.1   -24.57  3.85
GRID    60              159.1   -18.425 4.1
GRID    62              159.1   -12.28  4.05
GRID    64              159.1   -6.14   3.9
GRID    66              159.1   0.0     3.7
GRID    68              159.1   6.6     2.8
GRID    70              159.1   13.8    2.
GRID    72              159.1   17.1    .5
GRID    74              134.4   -39.    3.3
GRID    76              133.82  -32.5   3.7
GRID    78              133.23  -26.    4.1
GRID    80              132.65  -19.5   4.35
GRID    82              132.07  -13.    4.35
```

```
GRID    84              131.48  -6.5    4.2
GRID    86              130.9   0.0     4.
GRID    88              130.9   7.0     3.0
GRID    90              130.9   14.7    2.1
GRID    92              130.9   18.3    .5
GRID    94              111.35  -30.43  4.58
GRID    96              91.8    -42.7   3.6
GRID    98              91.8    -35.58  4.
GRID    102             91.8    -28.47  4.35
GRID    106             91.8    -21.35  .75
GRID    110             91.8    -14.23  .70
GRID    114             91.8    -7.12   4.5
GRID    116             91.8    0.0     4.35
GRID    118             91.8    7.6     3.3
GRID    120             91.8    16.     2.25
GRID    122             91.8    20.     .5
GRID    124             54.     -46.3   4.
GRID    126             54.     -38.58  4.35
GRID    130             54.     -30.87  4.85
GRID    134             54.     -23.15  5.15
GRID    138             54.     -15.43  5.1
GRID    142             54.     -7.72   4.88
GRID    144             54.     0.0     4.7
GRID    146             54.     8.2     3.55
GRID    148             54.     17.2    2.4
GRID    150             54.     21.6    .5
GRID    152             43.8    -47.2   4.
GRID    154             41.43   -39.33  4.5
GRID    156             39.07   -31.47  4.95
GRID    158             36.7    -23.6   5.25
GRID    160             34.33   -15.73  5.35
GRID    162             31.97   -7.87   5.1
GRID    164             29.6    0.0     5.
GRID    166             27.3    7.7     4.
GRID    168             25.     15.3    2.8
GRID    170             22.7    23.     .5
GRID    172             41.1    -49.    4.
GRID    174             36.28   -43.27  4.3
GRID    176             31.47   -37.53  4.75
GRID    178             26.65   -31.8   5.15
GRID    180             21.83   -26.07  5.4
GRID    182             17.02   -20.33  5.45
GRID    184             12.7    -14.6   5.45
GRID    186             .5      -.5     5.
GRID    188             -10.    11.5    3.6
GRID    190             -21.5   24.6    .5
GRID    192             23.7    -56.1   3.95
GRID    194             3.8     -21.7   5.
$
$       ****************************************************************
$       *                 CQDMEM PANELS - TOP OF WING                  *
$       ****************************************************************
$
CQDMEM  1       222251  1       3       15      13
CQDMEM  3       1       3       5       17      15
CQDMEM  5       1       5       7       19      17
CQDMEM  7       1       7       9       21      19
CQDMEM  9       1       9       11      23      21
CQDMEM  11      222251  13      15      35      33
CQDMEM  13      1       15      17      37      35
CQDMEM  15      1       17      19      39      37
CQDMEM  17      1       19      21      41      39
CQDMEM  19      1       21      23      43      41
CQDMEM  21      222251  23      25      45      43
CQDMEM  23      222251  25      27      47      45
CQDMEM  25      1       27      29      49      47
CQDMEM  27      1       29      31      51      49
CQDMEM  29      222251  33      35      55      53
CQDMEM  31      1       35      37      57      55
CQDMEM  33      1       37      39      59      57
CQDMEM  35      1       39      41      61      59
CQDMEM  37      1       41      43      63      61
CQDMEM  39      222251  43      45      65      63
CQDMEM  41      222251  45      47      67      65
CQDMEM  43      1       47      49      69      67
CQDMEM  45      1       49      51      71      69
CQDMEM  47      222251  53      55      75      73
CQDMEM  49      1       55      57      77      75
CQDMEM  51      1       57      59      79      77
CQDMEM  53      1       59      61      81      79
CQDMEM  55      1       61      63      83      81
CQDMEM  57      222251  63      65      85      83
CQDMEM  59      222251  65      67      87      85
CQDMEM  61      1       67      69      89      87
CQDMEM  63      1       69      71      91      89
CQDMEM  65      222252  73      75      97      95
CQDMEM  67      2       75      77      101     97
CQDMEM  69      222252  77      79      93      101
CQDMEM  71      222252  93      81      105     105
CQDMEM  73      2       81      83      113     109
CQDMEM  75      222252  83      85      115     113
CQDMEM  77      222252  85      87      117     115
CQDMEM  79      2       87      89      119     117
CQDMEM  81      2       89      91      121     119
CQDMEM  83      222252  95      97      125     123
CQDMEM  85      2       97      101     129     125
CQDMEM  89      2       101     105     133     129
CQDMEM  93      2       105     109     137     133
CQDMEM  97      2       109     113     141     137
CQDMEM  101     222252  113     115     143     141
CQDMEM  103     222252  115     117     145     143
CQDMEM  105     2       117     119     147     145
CQDMEM  107     2       119     121     149     147
CQDMEM  109     222252  123     125     153     151
CQDMEM  111     2       125     129     155     153
CQDMEM  113     2       129     133     157     155
CQDMEM  115     2       133     137     159     157
CQDMEM  117     2       137     141     161     159
CQDMEM  119     222252  141     143     163     161
CQDMEM  121     222252  143     145     165     163
CQDMEM  123     4       145     147     167     165
CQDMEM  125     4       147     149     169     167
CQDMEM  127     222252  151     153     173     171
CQDMEM  129     2       153     155     175     173
CQDMEM  131     2       155     157     177     175
CQDMEM  133     2       157     159     179     177
CQDMEM  135     2       159     161     181     179
CQDMEM  137     222252  161     163     183     181
CQDMEM  139     222252  163     165     185     183
CQDMEM  141     4       165     167     187     185
CQDMEM  143     4       167     169     189     187
$
$       ****************************************************************
$       *               CQDMEM PANELS - BOTTOM OF WING                 *
$       ****************************************************************
$
CQDMEM  2       222251  2       4       16      14
CQDMEM  4       1       4       6       18      16
CQDMEM  6       1       6       8       20      18
CQDMEM  8       1       8       10      22      20
CQDMEM  10      1       10      12      24      22
CQDMEM  12      222251  14      16      36      34
CQDMEM  14      1       16      18      38      36
CQDMEM  16      1       18      20      40      38
CQDMEM  18      1       20      22      42      40
CQDMEM  20      1       22      24      44      42
CQDMEM  22      222251  24      26      46      44
CQDMEM  24      222251  26      28      48      46
CQDMEM  26      1       28      30      50      48
CQDMEM  28      1       30      32      52      50
CQDMEM  30      222251  34      36      56      54
CQDMEM  32      1       36      38      58      56
CQDMEM  34      1       38      40      60      58
CQDMEM  36      1       40      42      62      60
CQDMEM  38      1       42      44      64      62
CQDMEM  40      222251  44      46      66      64
CQDMEM  42      222251  46      48      68      66
CQDMEM  44      1       48      50      70      68
CQDMEM  46      1       50      52      72      70
CQDMEM  48      222251  54      56      76      74
CQDMEM  50      1       56      58      78      76
CQDMEM  52      1       58      60      80      78
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CQDMEM  54      1       60      62      82      80
CQDMEM  56      1       62      64      84      82
CQDMEM  58      222251  64      66      86      84
CQDMEM  60      222251  66      68      88      86
CQDMEM  62      1       68      70      90      88
CQDMEM  64      1       70      72      92      90
CQDMEM  66      222251  74      76      96      94
CQDMEM  68      1       76      78      102     98
CQDMEM  70      222251  78      80      94      102
CQDMEM  78      222252  86      88      118     116
CQDMEM  80      2       88      90      120     118
CQDMEM  82      2       90      92      122     120
CQDMEM  102     222252  114     116     144     142
CQDMEM  104     222252  116     118     146     144
CQDMEM  106     2       118     120     148     146
CQDMEM  108     2       120     122     150     148
CQDMEM  110     222252  124     126     154     152
CQDMEM  112     4       126     130     156     154
CQDMEM  114     4       130     134     158     156
CQDMEM  116     4       134     138     160     158
CQDMEM  118     4       138     142     162     160
CQDMEM  120     222252  142     144     164     162
CQDMEM  122     222252  144     146     166     164
CQDMEM  124     4       146     148     168     166
CQDMEM  126     4       148     150     170     168
CQDMEM  128     222252  152     154     174     172
CQDMEM  130     4       154     156     176     174
CQDMEM  132     4       156     158     178     176
CQDMEM  134     4       158     160     180     178
CQDMEM  136     4       160     162     182     180
CQDMEM  138     222252  162     164     184     182
CQDMEM  140     222252  164     166     186     184
CQDMEM  142     4       166     168     188     186
CQDMEM  144     4       168     170     190     188
$
$       *************************************************************
$       *                 VERTICAL SHEAR PANELS                     *
$       *************************************************************
$
$       RIBS
CSHEAR  151     2222104 1       2       4       3
CSHEAR  152     2222104 3       4       6       5
CSHEAR  153     2222104 5       6       8       7
CSHEAR  154     2222104 7       8       10      9
CSHEAR  155     2222104 9       10      12      11
CSHEAR  156     2222104 11      12      26      25
CSHEAR  157     2222105 13      14      16      15
CSHEAR  158     2222105 15      16      18      17
CSHEAR  159     2222105 17      18      20      19
CSHEAR  160     2222105 19      20      22      21
CSHEAR  161     2222105 21      22      24      23
CSHEAR  162     2222105 23      24      26      25
CSHEAR  163     2222105 25      26      28      27
CSHEAR  164     2222105 27      28      30      29
CSHEAR  165     2222105 29      30      32      31
CSHEAR  166     2222107 33      34      36      35
CSHEAR  167     2222107 35      36      38      37
CSHEAR  168     2222107 37      38      40      39
CSHEAR  169     2222107 39      40      42      41
CSHEAR  170     2222107 41      42      44      43
CSHEAR  171     2222107 43      44      46      45
CSHEAR  172     2222108 45      46      48      47
CSHEAR  173     2222108 47      48      50      49
CSHEAR  174     2222108 49      50      52      51
CSHEAR  175     2222203 63      64      66      65
CSHEAR  176     2222203 65      66      68      67
CSHEAR  177     2222203 67      68      70      69
CSHEAR  178     2222203 69      70      72      71
CSHEAR  179     2222203 73      74      76      75
CSHEAR  180     2222203 75      76      78      77
CSHEAR  181     2222203 77      78      80      79
CSHEAR  182     2222203 79      80      82      81
CSHEAR  183     2222203 81      82      84      83
CSHEAR  184     2222203 83      84      86      85
CSHEAR  185     2222204 85      86      88      87
CSHEAR  186     2222204 87      88      90      89
CSHEAR  187     2222304 89      90      92      91
CSHEAR  188     2222403 95      96      98      97
CSHEAR  189     2222403 97      98      102     101
CSHEAR  191     2222404 101     102     106     105
CSHEAR  193     2222404 105     106     110     109
CSHEAR  195     2222403 109     110     114     113
CSHEAR  197     2222403 113     114     116     115
CSHEAR  198     2222405 115     116     118     117
CSHEAR  199     2222405 117     118     120     119
CSHEAR  200     2222405 119     120     122     121
CSHEAR  201     2222503 123     124     126     125
CSHEAR  202     2222503 125     126     130     129
CSHEAR  204     2222503 129     130     134     133
CSHEAR  206     2222503 133     134     138     137
CSHEAR  208     2222503 137     138     142     141
CSHEAR  210     2222503 141     142     144     143
CSHEAR  211     2222504 143     144     146     145
CSHEAR  212     2222504 145     146     148     147
CSHEAR  213     2222504 147     148     150     149
CSHEAR  214     2222602 151     152     154     153
CSHEAR  215     2222602 153     154     156     155
CSHEAR  216     2222602 155     156     158     157
CSHEAR  217     2222602 157     158     160     159
CSHEAR  218     2222602 159     160     162     161
CSHEAR  219     2222602 161     162     164     163
CSHEAR  220     2222603 163     164     166     165
CSHEAR  221     2222603 165     166     168     167
CSHEAR  222     2222603 167     168     170     169
CSHEAR  223     2222701 171     172     174     173
CSHEAR  224     2222701 173     174     176     175
CSHEAR  225     2222701 175     176     178     177
CSHEAR  226     2222701 177     178     180     179
CSHEAR  227     2222701 179     180     182     181
CSHEAR  228     2222701 181     182     184     183
CSHEAR  229     2222702 183     184     186     185
CSHEAR  230     2222702 185     186     188     187
CSHEAR  231     2222702 187     188     190     189
$       REAR SPAR
CSHEAR  232     2222101 1       2       14      13
CSHEAR  233     2222101 13      14      34      33
CSHEAR  234     2222101 53      33      34      54
CSHEAR  235     2222201 73      53      54      74
CSHEAR  236     2222301 95      73      74      96
CSHEAR  237     2222401 123     95      96      124
CSHEAR  238     2222502 151     123     124     152
CSHEAR  239     2222602 171     151     152     172
CSHEAR  240     2222603 191     171     172     192
$       WHEEL WELL
CSHEAR  241     2222305 93      81      82      94
CSHEAR  242     2222305 101     93      94      102
CQDMEM  243     15      141     113     114     142
$       FRONT SPAR
CSHEAR  244     2222102 45      25      26      46
CSHEAR  245     2222103 65      45      46      66
CSHEAR  246     2222202 85      65      66      86
CSHEAR  247     2222302 115     85      86      116
CSHEAR  248     2222402 143     115     116     144
CSHEAR  249     2222501 163     143     144     164
CSHEAR  250     2222601 183     163     164     184
CSHEAR  251     2222603 193     183     184     194
$       LEADING EDGE
CQDMEM  252     1       51      31      32      52
CQDMEM  253     1       71      51      52      72
CQDMEM  254     1       91      71      72      92
CQDMEM  255     2       121     91      92      122
CQDMEM  256     2       149     121     122     150
CQDMEM  257     4       169     149     150     170
CQDMEM  258     4       189     169     170     190
$
$       *************************************************************
$       *           PROPERTY CARDS FOR WEBS OF SPARS AND RIBS       *
$       *************************************************************
$
$           AWAY FROM DAMAGE:                BORDERING DAMAGE:
PSHEAR  2222101 11      .141            3333101 21      .141
PSHEAR  2222102 11      .329            3333102 21      .329
```

```
PSHEAR  2222103 11      .406            3333103 21      .406
PSHEAR  2222104 11      .066            3333104 21      .066
PSHEAR  2222105 11      .080            3333105 21      .080
PSHEAR  2222106 11      .095            3333106 21      .095
PSHEAR  2222107 11      .140            3333107 21      .140
PSHEAR  2222201 12      .141            3333201 22      .141
PSHEAR  2222202 12      .406            3333202 22      .406
PSHEAR  2222203 12      .095            3333203 22      .095
PSHEAR  2222301 13      .219            3333301 23      .219
PSHEAR  2222302 13      .300            3333302 23      .300
PSHEAR  2222303 13      .212            3333303 23      .212
PSHEAR  2222304 13      .190            3333304 23      .190
PSHEAR  2222305 13      .182            3333305 23      .182
PSHEAR  2222401 14      .300            3333401 24      .300
PSHEAR  2222402 14      .246            3333402 24      .246
PSHEAR  2222403 14      .150            3333403 24      .150
PSHEAR  2222404 14      .411            3333404 24      .411
PSHEAR  2222405 14      .190            3333405 24      .190
PSHEAR  2222501 15      .371            3333501 25      .371
PSHEAR  2222502 15      .400            3333502 25      .400
PSHEAR  2222503 15      .204            3333503 25      .204
PSHEAR  2222504 15      .190            3333504 25      .190
PSHEAR  2222601 16      .320            3333601 26      .320
PSHEAR  2222602 16      .263            3333602 26      .263
PSHEAR  2222603 16      .300            3333603 26      .300
PSHEAR  2222701 17      .097            3333701 27      .097
PSHEAR  2222702 17      .065            3333702 27      .065
PSHEAR  2222801 18      .150            3333801 28      .150
PSHEAR  2222802 18      .400            3333802 28      .400
PSHEAR  2222803 18      .500            3333803 28      .500
PSHEAR  9999    99      0.001
$
$       ***************************************************************
$       *   PROPERTY CARDS FOR UNBUCKLED SKIN PANELS AWAY FROM DAMAGE  *
$       ***************************************************************
$
PQDMEM  1       1       .064            2       1       .081
PQDMEM  3       1       .128            4       1       .081
PQDMEM  5       1       .066            6       1       .05
PQDMEM  7       1       .14             8       1       .212
PQDMEM  9       1       .15             10      1       .411
PQDMEM  11      1       .204            12      1       .263
PQDMEM  13      1       .097            14      1       .182
PQDMEM  15      1       .1              16      1       .095
PQDMEM  17      1       .19             18      1       .3
PQDMEM  19      1       .065            20      1       .329
PQDMEM  21      1       .406            22      1       .141
PQDMEM  23      1       .219            24      1       .30
PQDMEM  25      1       .2              26      1       .246
PQDMEM  27      1       .371            28      1       .4
PQDMEM  29      1       .32             30      1       .5
PQDMEM  31      1       .15
$
$       ***************************************************************
$       *  PROPERTY CARDS FOR UNBUCKLED SKIN PANELS ADJACENT TO DAMAGE *
$       ***************************************************************
$
PQDMEM  11111   2       .064            11112   2       .081
PQDMEM  11113   2       .128            11114   2       .081
PQDMEM  11115   2       .066            11116   2       .05
PQDMEM  11117   2       .14             11118   2       .212
PQDMEM  11119   2       .15             111110  2       .411
PQDMEM  111111  2       .204            111112  2       .263
PQDMEM  111113  2       .097            111114  2       .182
PQDMEM  111115  2       .1              111116  2       .095
PQDMEM  111117  2       .19             111118  2       .3
PQDMEM  111119  2       .065            111120  2       .329
PQDMEM  111121  2       .406            111122  2       .141
PQDMEM  111123  2       .219            111124  2       .30
PQDMEM  111125  2       .2              111126  2       .246
PQDMEM  111127  2       .371            111128  2       .4
PQDMEM  111129  2       .32             111130  2       .5
PQDMEM  111131  2       .15
$
$       ***************************************************************
$       *    PROPERTY CARDS FOR BUCKLED SKIN PANELS AWAY FROM DAMAGE   *
$       ***************************************************************
$
PQDMEM  22221   3       .064            22222   3       .081
PQDMEM  22223   3       .128            22224   3       .081
PQDMEM  22225   3       .066            22226   3       .05
PQDMEM  22227   3       .14             22228   3       .212
PQDMEM  22229   3       .15             222210  3       .411
PQDMEM  222211  3       .204            222212  3       .263
PQDMEM  222213  3       .097            222214  3       .182
PQDMEM  222215  3       .1              222216  3       .095
PQDMEM  222217  3       .19             222218  3       .3
PQDMEM  222219  3       .065            222220  3       .329
PQDMEM  222221  3       .406            222222  3       .141
PQDMEM  222223  3       .219            222224  3       .30
PQDMEM  222225  3       .2              222226  3       .246
PQDMEM  222227  3       .371            222228  3       .4
PQDMEM  222229  3       .32             222230  3       .5
PQDMEM  222231  3       .15
PQDMEM  222251  5       .064            222252  5       .081
$
$       ***************************************************************
$       *   PROPERTY CARDS FOR BUCKLED SKIN PANELS ADJACENT TO DAMAGE  *
$       ***************************************************************
$
PQDMEM  33331   4       .064            33332   4       .081
PQDMEM  33333   4       .128            33334   4       .081
PQDMEM  33335   4       .066            33336   4       .05
PQDMEM  33337   4       .14             33338   4       .212
PQDMEM  33339   4       .15             333310  4       .411
PQDMEM  333311  4       .204            333312  4       .263
PQDMEM  333313  4       .097            333314  4       .182
PQDMEM  333315  4       .1              333316  4       .095
PQDMEM  333317  4       .19             333318  4       .3
PQDMEM  333319  4       .065            333320  4       .329
PQDMEM  333321  4       .406            333322  4       .141
PQDMEM  333323  4       .219            333324  4       .30
PQDMEM  333325  4       .2              333326  4       .246
PQDMEM  333327  4       .371            333328  4       .4
PQDMEM  333329  4       .32             333330  4       .5
PQDMEM  333331  4       .15
PQDMEM  333351  6       .064            333352  6       .081
$
$       ***************************************************************
$       *      PROPERTY CARDS FOR SKIN PANELS WHICH HAVE FAILED        *
$       ***************************************************************
$
PQDMEM  9999    99      0.01
$
$       ***************************************************************
$       *                       HORIZONTAL RODS                        *
$       ***************************************************************
$
$         TOP SURFACE:                          BOTTOM SURFACE:
CROD    301     42      1       3       302     42      2       4
CROD    303     44      3       5       304     44      4       6
CROD    305     45      5       7       306     45      6       8
CROD    307     46      7       9       308     46      8       10
CROD    309     46      9       11      310     46      10      12
CROD    311     45      11      25      312     45      12      26
CROD    313     220     13      1       314     213     14      2
CROD    315     200     15      3       316     201     16      4
CROD    317     200     17      5       318     201     18      6
CROD    319     200     19      7       320     201     20      8
CROD    321     200     21      9       322     201     22      10
CROD    323     200     23      11      324     201     24      12
CROD    325     70      13      15      326     57      14      16
CROD    327     71      15      17      328     58      16      18
CROD    329     71      17      19      330     58      18      20
CROD    331     72      19      21      332     59      20      22
CROD    333     72      21      23      334     59      22      24
CROD    335     71      23      25      336     58      24      26
CROD    337     44      25      27      338     44      26      28
CROD    339     43      27      29      340     43      28      30
CROD    341     42      29      31      342     42      30      32
CROD    343     221     33      13      344     214     34      14
CROD    345     200     35      15      346     201     36      16
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CROD    347     200     37      17      348     201     38      18
CROD    349     200     39      19      350     201     40      20
CROD    351     200     41      21      352     201     42      22
CROD    353     200     43      23      354     201     44      24
CROD    355     228     45      25      356     238     46      26
CROD    357     202     47      27      358     203     48      28
CROD    359     202     49      29      360     203     50      30
CROD    361     202     51      31      362     203     52      32
CROD    363     79      33      35      364     54      34      36
CROD    365     80      35      37      366     56      36      38
CROD    367     82      37      39      368     62      38      40
CROD    369     82      39      41      370     62      40      42
CROD    371     81      41      43      372     61      42      44
CROD    373     81      43      45      374     61      44      46
CROD    375     68      45      47      376     68      46      48
CROD    377     68      47      49      378     68      48      50
CROD    379     67      49      51      380     67      50      52
CROD    381     222     53      33      382     215     54      34
CROD    383     200     55      35      384     201     56      36
CROD    385     200     57      37      386     201     58      38
CROD    387     200     59      39      388     201     60      40
CROD    389     200     61      41      390     201     62      42
CROD    391     200     63      43      392     201     64      44
CROD    393     229     65      45      394     236     66      46
CROD    395     202     67      47      396     203     68      48
CROD    397     202     69      49      398     203     70      50
CROD    413     74      65      67      414     74      66      68
CROD    415     74      67      69      416     74      68      70
CROD    417     73      69      71      418     73      70      72
CROD    419     323     73      53      420     316     74      54
CROD    421     300     75      55      422     301     76      56
CROD    423     300     77      57      424     301     78      58
CROD    425     300     79      59      426     301     80      60
CROD    427     300     81      61      428     301     82      62
CROD    429     300     83      63      430     301     84      64
CROD    431     330     85      65      432     337     86      66
CROD    433     302     87      67      434     303     88      68
CROD    435     302     89      69      436     303     90      70
CROD    437     302     91      71      438     303     92      72
CROD    439     114     73      75      440     108     74      76
CROD    441     115     75      77      442     111     76      78
CROD    443     117     77      79      444     112     78      80
CROD    445     118     79      81      446     113     80      82
CROD    447     117     81      83      448     66      82      84
CROD    449     116     83      85      450     65      84      86
CROD    451     94      85      87      452     94      86      88
CROD    453     94      87      89      454     94      88      90
CROD    455     93      89      91      456     93      90      92
CROD    457     424     95      73      458     417     96      74
CROD    459     404     97      75      460     405     98      76
CROD    461     404     101     77      462     405     102     78
CROD    463     49      101     93      464     41      102     94
CROD    465     404     93      79      466     405     94      80
CROD    467     404     105     93
CROD    469     49      93      81      470     41      94      82
CROD    471     404     109     81
CROD    473     404     113     83
CROD    475     431     115     85      476     438     116     86
CROD    477     402     117     87      478     403     118     88
CROD    479     402     119     89      480     403     120     90
CROD    481     402     121     91      482     403     122     92
CROD    483     125     95      97      484     84      96      98
CROD    485     126     97      101     486     85      98      102
CROD    487     129     101     105     488     41      102     106
CROD    489     132     105     109     490     51      106     110
CROD    491     130     109     113     492     41      110     114
CROD    493     127     113     115     494     92      114     116
CROD    495     108     115     117     496     108     116     118
CROD    497     108     117     119     498     108     118     120
CROD    499     107     119     121     500     107     120     122
CROD    509     525     123     95      510     518     124     96
CROD    511     506     125     97
CROD    515     507     129     101
CROD    519     508     133     105
CROD    523     509     137     109
CROD    527     510     141     113     528     511     142     114
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CROD    529     532     143     115     530     539     144     116
CROD    531     502     145     117     532     503     146     118
CROD    533     502     147     119     534     503     148     120
CROD    535     502     149     121     536     503     150     122
CROD    537     119     123     125     538     86      124     126
CROD    539     120     125     129     540     87      126     130
CROD    543     122     129     133     544     88      130     134
CROD    547     127     133     137     548     84      134     138
CROD    551     122     137     141     552     88      138     142
CROD    555     121     141     143     556     123     142     144
CROD    557     134     143     145     558     134     144     146
CROD    559     134     145     147     560     134     146     148
CROD    561     133     147     149     562     133     148     150
CROD    563     626     151     123     564     619     152     124
CROD    565     604     153     125     566     605     154     126
CROD    567     604     155     129     568     605     156     130
CROD    569     604     157     133     570     605     158     134
CROD    571     604     159     137     572     605     160     138
CROD    573     604     161     141     574     605     162     142
CROD    575     633     163     143     576     640     164     144
CROD    577     602     165     145     578     603     166     146
CROD    579     602     167     147     580     603     168     148
CROD    581     602     169     149     582     603     170     150
CROD    583     102     151     153     584     100     152     154
CROD    585     106     153     155     586     101     154     156
CROD    587     109     155     157     588     103     156     158
CROD    589     111     157     159     590     105     158     160
CROD    591     110     159     161     592     104     160     162
CROD    593     109     161     163     594     102     162     164
CROD    595     125     163     165     596     125     164     166
CROD    597     125     165     167     598     125     166     168
CROD    599     124     167     169     600     124     168     170
CROD    601     805     171     151     602     806     172     152
CROD    603     706     173     153     604     706     174     154
CROD    605     706     175     155     606     705     176     156
CROD    607     706     177     157     608     705     178     158
CROD    609     706     179     159     610     705     180     160
CROD    611     712     181     161     612     705     182     162
CROD    613     734     183     163     614     741     184     164
CROD    615     702     185     165     616     703     186     166
CROD    617     702     187     167     618     703     188     168
CROD    619     702     189     169     620     703     190     170
CROD    621     52      171     173     622     50      172     174
CROD    623     54      173     175     624     51      174     176
CROD    625     55      175     177     626     52      176     178
CROD    627     55      177     179     628     53      178     180
CROD    629     55      179     181     630     53      180     182
CROD    631     55      181     183     632     53      182     184
CROD    633     80      183     185     634     80      184     186
CROD    635     78      185     187     636     78      186     188
CROD    637     69      187     189     638     69      188     190
CROD    639     803     191     171     640     804     192     172
CROD    641     808     193     183     642     807     194     184
CROD    399     202     71      51      400     203     72      52
CROD    401     69      53      55      402     69      54      56
CROD    403     69      55      57      404     69      56      58
CROD    405     69      57      59      406     69      58      60
CROD    407     69      59      61      408     69      60      62
CROD    409     69      61      63      410     69      62      64
CROD    411     69      63      65      412     69      64      66
CROD    711     802     123     151     712     801     124     152
$
$       ************************************************************
$       *                       VERTICAL RODS                      *
$       ************************************************************
$
CROD    650     5       57      58
CROD    651     5       59      60
CROD    652     5       61      62
CROD    653     5       63      64
CROD    1101    1       1       2       1102    1       3       4
CROD    1103    1       5       6       1104    1       7       8
CROD    1105    1       9       10      1106    1       11      12
CROD    1107    1       13      14      1108    1       15      16
CROD    1109    1       17      18      1110    1       19      20
CROD    1111    1       21      22      1112    1       23      24
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CROD    1113    1       25      26      1114    1       27      28
CROD    1115    1       29      30      1116    42      31      32
CROD    1117    1       33      34      1118    1       35      36
CROD    1119    1       37      38      1120    1       39      40
CROD    1121    1       41      42      1122    1       43      44
CROD    1123    1       45      46      1124    1       47      48
CROD    1125    1       49      50      1126    67      51      52
CROD    1127    1       53      54      1128    1       55      56
CROD    1129    1       65      66      1130    1       67      68
CROD    1131    1       69      70      1132    73      71      72
CROD    1133    1       73      74      1134    1       75      76
CROD    1135    1       77      78      1136    1       79      80
CROD    1137    1       81      82      1138    1       83      84
CROD    1139    1       85      86      1140    1       87      88
CROD    1141    1       89      90      1142    9       91      92
CROD    1143    1       93      94      1144    1       95      96
CROD    1145    1       97      98
CROD    1147    1       101     102
CROD    1149    1       105     106
CROD    1151    1       109     110
CROD    1153    1       113     114     1154    1       115     116
CROD    1155    1       117     118     1156    1       119     120
CROD    1157    107     121     122     1158    1       123     124
CROD    1159    1       125     126
CROD    1161    1       129     130
CROD    1163    1       133     134
CROD    1165    1       137     138
CROD    1167    1       141     142
CROD    1169    1       145     146     1170    1       147     148
CROD    1171    137     149     150     1172    1       151     152
CROD    1173    1       153     154     1174    1       155     156
CROD    1175    1       157     158     1176    1       159     160
CROD    1177    1       161     162
CROD    1179    1       165     166     1180    1       167     168
CROD    1181    138     169     170     1182    1       171     172
CROD    1183    1       173     174     1184    1       175     176
CROD    1185    1       177     178     1186    1       179     180
CROD    1187    1       181     182     1188    1       183     184
CROD    1189    1       185     186     1190    1       187     188
CROD    1191    98      189     190
CROD    1268    1       143     144
CROD    1278    1       163     164
$
$       ***********************************************************
$       *       PROPERTY CARDS FOR ROD ELEMENTS AWAY FROM DAMAGE    *
$       ***********************************************************
$
$       FOR RODS BETWEEN SPARS, PANELS 6 AND 7
PROD    200     11      0.364
PROD    201     11      0.214
PROD    202     11      0.2476
PROD    203     11      0.3184
PROD    204     11      0.386
PROD    205     11      0.001
PROD    206     11      0.9515
PROD    207     11      1.292
PROD    208     11      1.362
PROD    209     11      1.152
PROD    210     11      0.748
PROD    211     11      0.478
PROD    212     11      0.380
$       FOR RODS BETWEEN FORWARD SPAR AND LEADING EDGE AND
$       FOR RODS BETWEEN SPARS, PANELS 1 THRU 5
PROD    302     12      0.2476
PROD    303     12      0.3184
PROD    300     12      0.364
PROD    301     12      0.214
PROD    402     13      0.2476
PROD    403     13      0.3184
PROD    404     13      0.386
PROD    406     13      0.001
PROD    502     14      0.2476
PROD    503     14      0.3184
PROD    506     14      0.9515
PROD    507     14      1.292
PROD    508     14      1.362
PROD    509     14      1.125
PROD    510     14      0.748
PROD    511     14      0.478
PROD    602     15      0.2476
PROD    603     15      0.3184
PROD    604     15      0.386
PROD    605     15      0.001
PROD    702     16      0.2476
PROD    703     16      0.3184
PROD    705     16      0.001
PROD    706     16      0.386
PROD    712     16      0.396
$       FOR RODS IN BOTH SPARS
PROD    213     11      0.719
PROD    214     11      0.794
PROD    215     11      0.844
PROD    316     12      0.862
PROD    417     13      1.736
PROD    518     14      2.86
PROD    619     15      3.898
PROD    720     16      3.807
PROD    220     11      0.749
PROD    221     11      0.824
PROD    222     11      0.854
PROD    323     12      0.882
PROD    424     13      1.207
PROD    525     14      2.24
PROD    626     15      3.776
PROD    727     16      3.812
PROD    228     11      0.404
PROD    229     11      0.395
PROD    330     12      0.440
PROD    431     13      1.656
PROD    532     14      2.672
PROD    633     15      3.111
PROD    734     16      4.833
PROD    235     11      0.399
PROD    236     11      0.450
PROD    337     12      0.424
PROD    438     13      1.311
PROD    539     14      3.062
PROD    640     15      2.807
PROD    741     16      5.716
PROD    801     18      0.69
PROD    802     18      0.73
PROD    803     18      2.84
PROD    804     18      3.04
PROD    805     18      4.10
PROD    806     18      4.35
PROD    807     18      4.64
PROD    808     18      5.02
$       FOR RODS IN RIBS AND FOR ALL VERTICAL RODS
PROD    1       15      .001
PROD    5       15      .20
PROD    9       15      .33
PROD    41      15      1.02
PROD    42      15      1.03
PROD    43      15      1.04
PROD    44      15      1.05
PROD    45      15      1.06
PROD    45      15      1.07
PROD    49      15      1.18
PROD    50      15      1.29
PROD    51      15      1.30
PROD    52      15      1.31
PROD    53      15      1.32
PROD    54      15      1.33
PROD    55      15      1.34
PROD    56      15      1.37
PROD    57      15      1.39
PROD    58      15      1.40
PROD    59      15      1.41
PROD    61      15      1.49
PROD    62      15      1.50
PROD    65      15      1.65
PROD    66      15      1.67
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PROD    67      15      1.68
PROD    68      15      1.69
PROD    69      15      1.70
PROD    70      15      1.73
PROD    71      15      1.74
PROD    72      15      1.75
PROD    73      15      1.78
PROD    74      15      1.79
PROD    78      15      1.86
PROD    79      15      1.89
PROD    80      15      1.92
PROD    81      15      1.94
PROD    82      15      1.96
PROD    84      15      2.00
PROD    85      15      2.02
PROD    86      15      2.04
PROD    87      15      2.08
PROD    88      15      2.10
PROD    92      15      2.31
PROD    93      15      2.57
PROD    94      15      2.58
PROD    96      15      2.67
PROD    100     15      3.05
PROD    101     15      3.10
PROD    102     15      3.13
PROD    103     15      3.14
PROD    104     15      3.15
PROD    105     15      3.17
PROD    106     15      3.18
PROD    107     15      3.19
PROD    108     15      3.20
PROD    109     15      3.21
PROD    110     15      3.22
PROD    111     15      3.23
PROD    112     15      3.26
PROD    113     15      3.27
PROD    114     15      3.36
PROD    115     15      3.38
PROD    116     15      3.40
PROD    117     15      3.41
PROD    118     15      3.42
PROD    119     15      3.58
PROD    120     15      3.62
PROD    121     15      3.63
PROD    122     15      3.64
PROD    123     15      3.97
PROD    124     15      4.00
PROD    125     15      4.02
PROD    126     15      4.04
PROD    127     15      4.06
PROD    129     15      4.22
PROD    130     15      4.23
PROD    132     15      4.37
PROD    133     15      4.42
PROD    134     15      4.43
PROD    137     15      5.40
PROD    138     15      5.80
$
$     ************************************************************
$     *        PROPERTY CARDS FOR ROD ELEMENTS ADJACENT TO DAMAGE   *
$     ************************************************************
$
$     FOR RODS BETWEEN SPARS, PANELS 6 AND 7
PROD      8888200 21      0.364
PROD      8888201 21      0.214
PROD      8888202 21      0.2476
PROD      8888203 21      0.3184
PROD      8888204 21      0.386
PROD      8888205 21      0.001
PROD      8888206 21      0.9515
PROD      8888207 21      1.292
PROD      8888208 21      1.362
PROD      8888209 21      1.152
PROD      8888210 21      0.748
PROD      8888211 21      0.478
PROD      8888212 21      0.380
$     FOR RODS BETWEEN FRONT SPAR AND LEADING EDGE AND
$     FOR RODS BETWEEN SPARS, PANELS 1 THRU 5
PROD      8888302 22      0.2476
PROD      8888303 22      0.3184
PROD      8888300 22      0.364
PROD      8888301 22      0.214
PROD      8888402 23      0.2476
PROD      8888403 23      0.3184
PROD      8888404 23      0.386
PROD      8888405 23      0.001
PROD      8888502 24      0.2476
PROD      8888503 24      0.3184
PROD      8888506 24      0.9515
PROD      8888507 24      1.292
PROD      8888508 24      1.362
PROD      8888509 24      1.125
PROD      8888510 24      0.748
PROD      8888511 24      0.478
PROD      8888602 25      0.2476
PROD      8888603 25      0.3184
PROD      8888604 25      0.386
PROD      8888605 25      0.001
PROD      8888702 26      0.2476
PROD      8888703 26      0.3184
PROD      8888705 26      0.001
PROD      8888706 26      0.386
PROD      8888712 26      0.386
$     FOR RODS IN BOTH SPARS
PROD      8888213 21      0.718
PROD      8888214 21      0.794
PROD      8888215 21      0.844
PROD      8888316 22      -0.862
PROD      8888417 23      1.736
PROD      8888518 24      2.86
PROD      8888619 25      3.698
PROD      8888720 26      3.807
PROD      8888220 21      0.749
PROD      8888221 21      0.824
PROD      8888222 21      0.854
PROD      8888323 22      0.882
PROD      8888424 23      1.207
PROD      8888525 24      2.24
PROD      8888626 25      3.776
PROD      8888727 26      3.812
PROD      8888228 21      0.404
PROD      8888229 21      0.395
PROD      8888330 22      0.440
PROD      8888331 23      1.656
PROD      8888532 24      2.672
PROD      8888633 25      3.111
PROD      8888734 26      4.833
PROD      8888235 21      0.389
PROD      8888236 21      0.450
PROD      8888337 22      0.424
PROD      8888438 23      1.311
PROD      8888539 24      3.062
PROD      8888640 25      2.607
PROD      8888741 26      5.718
PROD      8888801 18      0.69
PROD      8888802 18      0.73
PROD      8888803 18      2.84
PROD      8888804 18      3.04
PROD      8888805 18      4.10
PROD      8888806 18      4.38
PROD      8888807 18      4.84
PROD      8888808 18      5.02
$     FOR RODS IN RIBS AND FOR ALL VERTICAL RODS
PROD      88881   25      .001
PROD      88885   25      .20
PROD      88889   25      .33
PROD      888841  25      1.02
PROD      888842  25      1.03
PROD      888843  25      1.04
PROD      888844  25      1.05
PROD      888845  25      1.06
PROD      888846  25      1.07
```

```
PROD    888849  25      1.18
PROD    888850  25      1.29
PROD    888851  25      1.30
PROD    888852  25      1.31
PROD    888853  25      1.32
PROD    888854  25      1.33
PROD    888855  25      1.34
PROD    888856  25      1.37
PROD    888857  25      1.38
PROD    888858  25      1.40
PROD    888859  25      1.41
PROD    888861  25      1.49
PROD    888862  25      1.50
PROD    888865  25      1.65
PROD    888866  25      1.67
PROD    888867  25      1.68
PROD    888868  25      1.69
PROD    888869  25      1.70
PROD    888870  25      1.73
PROD    888871  25      1.74
PROD    888872  25      1.75
PROD    888873  25      1.78
PROD    888874  25      1.79
PROD    888878  25      1.86
PROD    888879  25      1.89
PROD    888880  25      1.92
PROD    888881  25      1.94
PROD    888882  25      1.96
PROD    888884  25      2.00
PROD    888885  25      2.02
PROD    888886  25      2.04
PROD    888887  25      2.06
PROD    888888  25      2.10
PROD    888892  25      2.31
PROD    888893  25      2.57
PROD    888894  25      2.58
PROD    888896  25      2.67
PROD    8888100 25      3.08
PROD    8888101 25      3.10
PROD    8888102 25      3.13
PROD    8888103 25      3.14
PROD    8888104 25      3.15
PROD    8888105 25      3.17
PROD    8888106 25      3.18
PROD    8888107 25      3.19
PROD    8888108 25      3.20
PROD    8888109 25      3.21
PROD    8888110 25      3.22
PROD    8888111 25      3.23
PROD    8888112 25      3.26
PROD    8888113 25      3.27
PROD    8888114 25      3.36
PROD    8888115 25      3.38
PROD    8888116 25      3.40
PROD    8888117 25      3.41
PROD    8888118 25      3.42
PROD    8888119 25      3.58
PROD    8888120 25      3.62
PROD    8888121 25      3.63
PROD    8888122 25      3.64
PROD    8888123 25      3.97
PROD    8888124 25      4.00
PROD    8888125 25      4.02
PROD    8888126 25      4.04
PROD    8888127 25      4.08
PROD    8888129 25      4.22
PROD    8888130 25      4.23
PROD    8888132 25      4.37
PROD    8888133 25      4.42
PROD    8888134 25      4.43
PROD    8888137 25      5.40
PROD    8888138 25      5.80
$
$       ****************************************************************
$       *       PROPERTY CARDS FOR ROD ELEMENTS WHICH HAVE FAILED      *
$       ****************************************************************
```

```
$
PROD    9999    99      0.01
$
$       ****************************************************************
$       *                       ELASTIC SPRINGS                        *
$       ****************************************************************
$
CELAS2  9490    7.633+3 102     1       106     1
CELAS2  9494    1.1+4   106     1       110     1
CELAS2  9498    7.633+3 110     1       114     1
$
$       ****************************************************************
$       *                     TRIANGULAR MEMBERS                       *
$       ****************************************************************
$
CTRMEM  275     222251  23      11      25
CTRMEM  276     222251  24      12      26
CTRMEM  277     222252  93      79      81
CTRMEM  278     222252  94      80      82
CTRMEM  279     222252  101     93      105
PTRMEM  1       1       0.064           2       1       0.081
PTRMEM  11111   2       0.064           11112   2       0.081
PTRMEM  22221   3       0.064           22222   3       0.081
PTRMEM  33331   4       0.064           33332   4       0.081
PTRMEM  222251  5       0.064           222252  5       0.081
PTRMEM  333351  6       0.064           333352  6       0.081
PTRMEM  9999    99      0.01
$
$       ****************************************************************
$       *                  SINGLE POINT CONSTRAINTS                    *
$       ****************************************************************
$
SPC     100     191     1       0.0     191     2       0.0
SPC     100     192     1       0.0     192     2       0.0
SPC     100     193     1       0.0     193     2       0.0
SPC     100     194     1       0.0     194     2       0.0
SPC     100     191     3               192     3
SPC     100     193     3               194     3
$       ****************************************************************
$       SPC ID NUMBERS ARE THE APPLIED LOAD IN KIPS
$       SPC VALUES SHOWN ARE FOR TEST 3B
SPC     2       191     1       +.031   191     2       0.009
SPC     2       191     3       -.080   192     3       -.080
SPC     2       192     1       -.031   192     2       -.009
SPC     2       193     1       +.034   193     2       0.014
SPC     2       193     3       -.006   194     3       -.006
SPC     2       194     1       -.034   194     2       -.014
SPC     4       191     1       +.050   191     2       0.017
SPC     4       191     3       -.135   192     3       -.135
SPC     4       192     1       -.050   192     2       -.017
SPC     4       193     1       +.051   193     2       0.021
SPC     4       193     3       -.055   194     3       -.055
SPC     4       194     1       -.051   194     2       -.021
SPC     6       191     1       +.064   191     2       0.022
SPC     6       191     3       -.165   192     3       -.165
SPC     6       192     1       -.064   192     2       -.022
SPC     6       193     1       +.061   193     2       0.022
SPC     6       193     3       -.075   194     3       -.075
SPC     6       194     1       -.061   194     2       -.022
SPC     8       191     1       +.073   191     2       0.021
SPC     8       191     3       -.195   192     3       -.195
SPC     8       192     1       -.073   192     2       -.021
SPC     8       193     1       +.067   193     2       0.021
SPC     8       193     3       -.082   194     3       -.082
SPC     8       194     1       -.067   194     2       -.021
SPC     10      191     1       +.080   191     2       0.018
SPC     10      191     3       -.210   192     3       -.210
SPC     10      192     1       -.080   192     2       -.018
SPC     10      193     1       +.071   193     2       0.019
SPC     10      193     3       -.085   194     3       -.085
SPC     10      194     1       -.071   194     2       -.019
SPC     12      191     1       +.090   191     2       0.017
SPC     12      191     3       -.215   192     3       -.215
SPC     12      192     1       -.090   192     2       -.017
SPC     12      193     1       +.075   193     2       0.018
SPC     12      193     3       -.085   194     3       -.085
```

```
SPC     12      194     1       -.075   194     2       -.018
$
$       ****************************************************************
$       *                    MULTIPOINT CONSTRAINTS                    *
$       ****************************************************************
$
MPC     100     184     1       .34     184     1       -1.0
MPC     100     184     2       .33     184     2       -1.0
MPC     100     183     1       .36     183     1       -1.0
MPC     100     183     2       .34     183     2       -1.0
MPC     100     152     1       .76     172     1       -1.0
MPC     100     151     1       .76     171     1       -1.0
MPC     100     152     2       .8      172     2       -1.0
MPC     100     151     2       .8      171     2       -1.0
MPC     100     96      2       -1.0    74      2       .53             +MPC1
+MPC1           152     2       .47
MPC     100     124     2       -1.0    74      2       .11             +MPC2
+MPC2           152     2       .89
MPC     100     84      1       .48     142     1       .52             +MPC3
+MPC3           114     1       -1.
MPC     100     78      1       .48     130     1       .52             +MPC4
+MPC4           102     1       -1.0
MPC     100     76      1       .48     126     1       .52             +MPC5
+MPC5           96      1       -1.0
MPC     100     82      1       .48     138     1       .52             +MPC6
+MPC6           110     1       -1.0
MPC     100     94      1       .66     134     1       .34             +MPC7
+MPC7           106     1       -1.0
$
$       ****************************************************************
$       *     MATERIAL CARDS FOR SPARS AND RIBS AWAY FROM DAMAGE       *
$       ****************************************************************
$
MAT1    11      10.3+6  3.9+6           3.14-3                          +M11
+M11    3.75+4  3.75+4  3.83+4
MAT1    12      10.3+6  3.9+6           3.14-3                          +M12
+M12    5.51+4  5.51+4  3.83+4
MAT1    13      10.3+6  3.9+6           3.14-3                          +M13
+M13    5.91+4  5.91+4  3.83+4
MAT1    14      10.3+6  3.9+6           3.14-3                          +M14
+M14    6.41+4  6.41+4  3.83+4
MAT1    15      10.3+6  3.9+6           3.14-3                          +M15
+M15    6.91+4  6.91+4  3.83+4
MAT1    16      10.3+6  3.9+6           3.14-3                          +M16
+M16    7.03+4  7.03+4  3.83+4
MAT1    17      10.3+6  3.9+6           3.14-3                          +M17
+M17    7.27+4  7.27+4  3.83+4
MAT1    18      30.0+6  11.0+6          8.73-3                          +M18
+M18    22.8+4  22.8+4  12.33+4
$     MATERIALS 11 THRU 17 ARE FOR ALUMINUM 1-D AND 2-D
$      ELEMENTS AWAY FROM DAMAGE. BASIC LIMITING
$      STRESSES ARE: T&C= 7.5+4 AND S= 4.5+4.
$      THE BASIC LIMITING STRESSES FOR T&C ARE FACTORED
$      AS FOLLOWS USING FORMAT (MID:FACTOR)
$      (11:.5000) (12:.7350) (13:.7882) (14:.8547)
$      (15:.9210) (16:.9369) (17:.9697)
$
$     MATERIAL 18 IS FOR STEEL 1-D AND 2-D ELEMENTS AWAY
$     WITH LIMITING STRESSES T&C= 240+3 AND S= 145+3.
$     THE FACTOR FOR T&C IS (18:.9500)
$
$     THE FACTOR FOR S FOR ALL MID NUMBERS IS 0.8500
$
$       ****************************************************************
$       *     MATERIAL CARDS FOR SPARS AND RIBS BORDERING DAMAGE       *
$       ****************************************************************
$
MAT1    21      10.3+6  3.9+6           3.14-3                          +M21
+M21    1.80+4  3.75+4  2.77+4
MAT1    22      10.3+6  3.9+6           3.14-3                          +M22
+M22    2.64+4  5.51+4  2.77+4
MAT1    23      10.3+6  3.9+6           3.14-3                          +M23
+M23    2.84+4  5.91+4  2.77+4
MAT1    24      10.3+6  3.9+6           3.14-3                          +M24
+M24    3.08+4  6.41+4  2.77+4
MAT1    25      10.3+6  3.9+6           3.14-3                          +M25
+M25    3.32+4  6.91+4  2.77+4
MAT1    26      10.3+6  3.9+6           3.14-3                          +M26
+M26    3.37+4  7.03+4  2.77+4
MAT1    27      10.3+6  3.9+6           3.14-3                          +M27
+M27    3.49+4  7.27+4  2.77+4
MAT1    28      30.0+6  11.0+6          8.73-3                          +M28
+M28    10.9+4  22.8+4  8.94+4
$
$     MATERIALS 21 THRU 28 ARE FOR 1-D AND 2-D ELEMENTS
$      BORDERING DAMAGE AND CORRESPOND TO MATERIALS 11 THRU 18
$      RESPECTIVELY.  PREVIOUS LIMITING STRESSES ARE FURTHER
$      FACTORED AS FOLLOWS:  (T:.480) (C:1.00) (S:.725)
$
$       ****************************************************************
$       *              MATERIAL CARDS FOR SKIN PANEL ELEMENTS          *
$       ****************************************************************
$
MAT1    1       10.3+6  3.9+6           3.14-3                          +M1
+M1     4.24+4  1.28+4  1.49+4
MAT1    2       10.3+6  3.9+6           3.14-3                          +M2
+M2     4.24+4  1.28+4  1.49+4
MAT1    3       7.79+6  2.05+6          3.14-3                          +M3
+M3     7.70+4  7.70+4  4.60+4
MAT1    4       7.79+6  2.05+6          3.14-3                          +M4
+M4     3.67+4  7.70+4  3.34+4
$
$     MATERIALS 1 THRU 4 ARE FOR ALUMINUM SKIN PANELS.
$      THEY ARE FOR:  1 - UNBUCKLED AWAY FROM DAMAGE
$                     2 - UNBUCKLED BORDERING DAMAGE
$                     3 - BUCKLED AWAY FROM DAMAGE
$                     4 - BUCKLED BORDERING DAMAGE
$      BASIC LIMITING STRESSES ARE:  T&C=7 7+4  AND  S=4.6+4
$      THE BASIC LIMITING STRESSES ARE FACTORED AS FOLLOWS
$      USING FORMAT (MID:TYPE STRESS:FACTOR)
$      (1:T:.8500) (1:C:.1657) (1:S:.3241)
$      (2:T:.8500) (2:C:.1657) (2:S:.3241)
$      (3:T:1.000) (3:C:1.000) (3:S:1.000)
$      (4:T:.4770) (4:C:1.000) (4:S:.7290)
$      POST-BUCKLING MODULUS REDUCTION FACTORS ARE:
$      (E:.7564) (G:.5254)
$
$
MAT1    5       10.3+6  3.9+6           3.14-3                          +M5
+M5     7.70+4  7.70+4  4.60+4
MAT1    6       10.3+6  3.9+6           3.14-3                          +M6
+M6     3.67+4  7.70+4  3.34+4
$
$     MATERIALS 5 AND 6 ARE FOR ALUMINUM SKIN PANELS BORDERING SPARS.
$      AWAY FROM DAMAGE AND BORDERING DAMAGE RESPECTIVELY.  NO
$      BUCKLING AND ORIGINAL STIFFNESSES ARE ASSUMED.  GENERAL
$      SKIN PANEL POST-BUCKLING LIMITING STRESSES ARE USED.
$
$       ****************************************************************
$       *    SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE    *
$       ****************************************************************
$
MAT1    99      10.0    5.0             3.14-3                          +M99
+M99    99.9+9  99.9+9  99.9+9
$
$
$
$
$       ****************************************************************
$       *                     MISCELLANEOUS CARDS                      *
$       ****************************************************************
$
GRDSET                                                  456
PARAM   GRDPNT  0
$       ****************************************************************
$       *                       APPLIED FORCES                         *
$       ****************************************************************
$
GRAV    3       0       386.4   0.0     0.0     -1.0
FORCE   1       33              500.    0.0     0.0     1.0
FORCE   1       34              500.    0.0     0.0     1.0
FORCE   2       45              500.    0.0     0.0     1.0
```

```
FORCE   2       46              500.    0.0     0.0     1.0
$       NET LOADING CONDITIONS
LOAD    101     1.0     1.0     1
LOAD    102     1.0     2.0     1
LOAD    103     1.0     3.0     1
LOAD    104     1.0     4.0     1
LOAD    105     1.0     5.0     1
LOAD    106     1.0     6.0     1
LOAD    107     1.0     7.0     1
LOAD    108     1.0     8.0     1
LOAD    109     1.0     9.0     1
LOAD    110     1.0     10.0    1
LOAD    111     1.0     11.0    1
LOAD    112     1.0     12.0    1
LOAD    113     1.0     13.0    1
LOAD    114     1.0     14.0    1
LOAD    115     1.0     15.0    1
LOAD    116     1.0     16.0    1
LOAD    117     1.0     17.0    1
LOAD    118     1.0     18.0    1
LOAD    119     1.0     19.0    1
LOAD    120     1.0     20.0    1
LOAD    121     1.0     21.0    1
LOAD    122     1.0     22.0    1
LOAD    123     1.0     23.0    1
LOAD    124     1.0     24.0    1
LOAD    125     1.0     25.0    1
LOAD    126     1.0     26.0    1
LOAD    127     1.0     27.0    1
LOAD    128     1.0     28.0    1
LOAD    129     1.0     29.0    1
LOAD    130     1.0     30.0    1
LOAD    131     1.0     31.0    1
LOAD    132     1.0     32.0    1
LOAD    133     1.0     33.0    1
LOAD    134     1.0     34.0    1
LOAD    135     1.0     35.0    1
LOAD    136     1.0     36.0    1
LOAD    137     1.0     37.0    1
LOAD    138     1.0     38.0    1
LOAD    139     1.0     39.0    1
LOAD    140     1.0     40.0    1
LOAD    141     1.0     41.0    1
LOAD    142     1.0     42.0    1
LOAD    143     1.0     43.0    1
LOAD    144     1.0     44.0    1
LOAD    145     1.0     45.0    1
$       GROSS LOADING CONDITIONS
LOAD    200     1.0     1.0     3
LOAD    201     1.0     1.0     1       1.0     3
LOAD    202     1.0     2.0     1       1.0     3
LOAD    203     1.0     3.0     1       1.0     3
LOAD    204     1.0     4.0     1       1.0     3
LOAD    205     1.0     5.0     1       1.0     3
LOAD    206     1.0     6.0     1       1.0     3
LOAD    207     1.0     7.0     1       1.0     3
LOAD    208     1.0     8.0     1       1.0     3
LOAD    209     1.0     9.0     1       1.0     3
LOAD    210     1.0     10.0    1       1.0     3
LOAD    211     1.0     11.0    1       1.0     3
LOAD    212     1.0     12.0    1       1.0     3
LOAD    213     1.0     13.0    1       1.0     3
LOAD    214     1.0     14.0    1       1.0     3
LOAD    215     1.0     15.0    1       1.0     3
LOAD    216     1.0     16.0    1       1.0     3
$
ENDDATA
```

APPENDIX F

FINITE ELEMENT TORSIONAL ROD LISTING

```
$
$       *************************************************************
$       *     THESE CARDS CONVERT WING MODEL A TO MODEL B, AND ALSO  *
$       *     CONVERT WING MODEL C TO MODEL D BY ADDING TORSIONAL    *
$       *     STIFFNESS TO THE FRONT SPAR AND TO THE REAR SPAR.      *
$       *************************************************************
$
$       COORDINATE SYSTEM DEFINITIONS FOR TORSION
CORD1R  2000    2184    184     2164    3000    3172    172     3152
$       GRID POINTS FOR FRONT SPAR CENTERLINE
GRID    2025            209.0   0.0     0.0             12356
GRID    2045            184.1   0.0     0.0             12356
GRID    2065            159.1   0.0     0.0             12356
GRID    2085            130.9   0.0     0.0             12356
GRID    2115            91.8    0.0     0.0             12356
GRID    2143            54.0    0.0     0.0             12356
GRID    2163            29.6    0.0     0.0             12356
GRID    2164            29.6    0.0     0.0     2000    12356
GRID    2184            12.7    -14.6   0.0     2000    12356
GRID    2194            3.88    -21.9   0.0     2000    12356
$       GRID POINTS FOR REAR SPAR CENTERLINE
GRID    3001            232.9   -30.4   0.0             12356
GRID    3013            209.0   -32.5   0.0             12356
GRID    3033            184.1   -34.7   0.0             12356
GRID    3053            159.1   -36.85  0.0             12356
GRID    3073            134.4   -39.0   0.0             12356
GRID    3095            91.8    -42.7   0.0             12356
GRID    3123            54.0    -46.3   0.0             12356
GRID    3151            43.8    -47.2   0.0             12356
GRID    3152            43.8    -47.2   0.0     3000    12356
GRID    3172            41.1    -49.0   0.0     3000    12356
GRID    3192            32.7    -56.1   0.0     3000    12356
$       CRODS FOR TORSION
CROD    2395    2001    2025    2045    3343    3001    3013    3033
CROD    2393    2002    2045    2065    3381    3001    3033    3053
CROD    2431    2002    2065    2085    3419    3001    3053    3073
CROD    2479    2003    2085    2115    3457    3002    3073    3095
CROD    2529    2004    2115    2143    3509    3003    3095    3123
CROD    2575    2005    2143    2163    3563    3004    3123    3151
CROD    2613    2006    2164    2184    3601    3005    3152    3172
CROD    2641    2007    2184    2194    3639    3006    3172    3192
CROD    3313    3001    3001    3013
$       PROD CARDS FOR TORSION RODS AWAY FROM DAMAGE
PROD    2001    11      0.0     0.007   0.055
PROD    2002    11      0.0     0.014   0.143
PROD    2003    13      0.0     0.212   0.370
PROD    2004    14      0.0     0.347   0.246
PROD    2005    15      0.0     3.827   0.371
PROD    2006    16      0.0     12.443  0.320
PROD    2007    18      0.0     11.587  0.150
PROD    3001    11      0.0     0.006   0.080
PROD    3002    13      0.0     0.035   0.125
PROD    3003    14      0.0     0.813   0.200
PROD    3004    15      0.0     8.710   0.400
PROD    3005    18      0.0     2.247   0.400
PROD    3006    18      0.0     2.272   0.500
$       PROD CARDS FOR TORSION RODS BORDERING DAMAGE
PROD    88882001 21     0.0     0.007   0.055
PROD    88882002 21     0.0     0.014   0.142
PROD    88882003 23     0.0     0.212   0.370
PROD    88882004 24     0.0     0.347   0.246
PROD    88882005 25     0.0     3.827   0.371
PROD    88882006 26     0.0     12.443  0.320
PROD    88882007 28     0.0     11.587  0.150
PROD    88883001 21     0.0     0.006   0.080
PROD    88883002 23     0.0     0.035   0.125
PROD    88883003 24     0.0     0.813   0.200
PROD    88883004 25     0.0     8.710   0.400
PROD    88883005 28     0.0     2.247   0.400
PROD    88883006 28     0.0     2.272   0.500
$       SINGLE POINT CONSTRAINT COMBINATION CARD FOR TORSION
SPCADD  300     100     200
$       SINGLE POINT CONSTRAINT CARD FOR TORSION
SPC     200     2194    4       0.0     3192    4       0.0
$       MULTI POINT CONSTRAINT COMBINATION CARDS FOR TORSION
MPCADD  1000    2000    3000    4000    100
MPCADD  1001    2000    3000    100
```

```
$       FRONT SPAR MULTI POINT CONSTRAINT CARDS FOR TORSION
MPC     2000    2025    4       6.90    25      2       -1.0            +MP2001
+MP2001         26      2       +1.0
MPC     2000    2045    4       7.00    45      2       -1.0            +MP2002
+MP2002         46      2       +1.0
MPC     2000    2065    4       7.40    65      2       -1.0            +MP2003
+MP2003         66      2       +1.0
MPC     2000    2085    4       8.00    85      2       -1.0            +MP2004
+MP2004         86      2       +1.0
MPC     2000    2115    4       8.70    115     2       -1.0            +MP2005
+MP2005         116     2       +1.0
MPC     2000    2143    4       9.40    143     2       -1.0            +MP2006
+MP2006         144     2       +1.0
MPC     2000    2163    4       10.0    163     2       -1.0            +MP2007
+MP2007         164     2       +1.0
MPC     2000    2164    4       10.0    163     1       0.6537          +MP2008A
+MP2008A        163     2       -0.7567 164     1       -0.6537         +MP2008B
+MP2008B        164     2       0.7567
MPC     2000    2184    4       10.9    183     1       0.6537          +MP2009A
+MP2009A        183     2       -0.7567 184     1       -0.6537         +MP2009B
+MP2009B        184     2       0.7567
MPC     4000    2194    4       10.0    193     1       0.6537          +MP2010A
+MP2010A        193     2       -0.7567 194     1       -0.6537         +MP2010B
+MP2010B        194     2       0.7567
$       REAR SPAR MULTI POINT CONSTRAINT CARDS FOR TORSION
MPC     3000    3013    4       9.30    13      2       -1.0            +MP3001
+MP3001         14      2       +1.0
MPC     3000    3033    4       5.70    33      2       -1.0            +MP3002
+MP3002         34      2       +1.0
MPC     3000    3053    4       6.10    53      2       -1.0            +MP3003
+MP3003         54      2       +1.0
MPC     3000    3073    4       6.60    73      2       -1.0            +MP3004
+MP3004         74      2       +1.0
MPC     3000    3095    4       7.20    95      2       -1.0            +MP3005
+MP3005         96      2       +1.0
MPC     3000    3123    4       8.00    123     2       -1.0            +MP3006
+MP3006         124     2       +1.0
MPC     3000    3151    4       8.00    151     2       -1.0            +MP3007
+MP3007         152     2       +1.0
MPC     3000    3152    4       8.00    151     1       0.5547          +MP3008A
+MP3008A        151     2       -0.8321 152     1       -0.5547         +MP3008B
+MP3008B        152     2       0.8321
MPC     3000    3172    4       8.00    171     1       0.5547          +MP3009A
+MP3009A        171     2       -0.8321 172     1       -0.5547         +MP3009B
+MP3009B        172     2       0.8321
MPC     4000    3192    4       7.90    191     1       0.5547          +MP3010A
+MP3010A        191     2       -0.8321 192     1       -0.5547         +MP3010B
+MP3010B        192     2       0.8321
MPC     3000    3001    4       5.00    1       2       -1.0            +MP3011
+MP3011         2       2       +1.0
$
$       *************************************************************
$       *          SPECIAL CARDS NEEDED FOR INITIAL DAMAGE          *
$       *************************************************************
$
$       CARDS FOR INITIAL DAMAGE FOR TEST 3B:
SCROD   2529    9002    2115    2143    3509    88889001 3095   3123
PROD    9001    14      0.0     0.308   0.400
PROD    9002    14      0.0     3.044   0.450
PROD    88889001 24     0.0     0.308   0.400
PROD    88889002 24     0.0     3.044   0.450
$
$       CARDS FOR INITIAL DAMAGE FOR TEST 2C:
SCROD   2529    2004    2115    2143    3509    9003    3095    3123
PROD    9003    99      0.0     0.00001 0.00001
$
$       CARDS FOR INITIAL DAMAGE FOR TEST 1:
SCROD   2529    88889004 2115   2143    3509    3003    3095    3123
PROD    88889004 24     0.0     1.9587  1.000
```

APPENDIX G

FINITE ELEMENT INITIAL DAMAGE MODELING

```
$$      ****************************************************************
$$      *           BULK DATA DECK FOR TEST 1 (SIMPLE DAMAGE)          *
$$      *              F-84F WING PROJECT - DAMAGED WING               *
$$      *                   MODEL A - STATIC CASE                      *
$$      *               SPARS AND RIBS.  CROD AND CSHEAR               *
$$      *                    STIFFENERS:  CROD                         *
$$      *                   SKIN PANELS:  CSHEAR                       *
$$      *             NO TORSIONAL STIFFNESS IN SPARS                  *
$$      ****************************************************************
$$
$$      ****************************************************************
$$      *                SHEAR PANELS - TOP OF WING                    *
$$      ****************************************************************
$$
$$      CHANGE CSHEAR 73   NEW PID=11112    OLD PID=2
$$      CHANGE CSHEAR 75   NEW PID=333352   OLD PID=222252
$$      CHANGE CSHEAR 77   NEW PID=333352   OLD PID=222252
$$      CHANGE CSHEAR 79   NEW PID=11112    OLD PID=2
$$      CHANGE CSHEAR 97   NEW PID=11112    OLD PID=2
$$      CHANGE CSHEAR 101  NEW PID=9999     OLD PID=222252
$$      CHANGE CSHEAR 103  NEW PID=9999     OLD PID=222252
$$      CHANGE CSHEAR 105  NEW PID=11112    OLD PID=2
$$      CHANGE CSHEAR 117  NEW PID=11112    OLD PID=2
$$      CHANGE CSHEAR 119  NEW PID=333352   OLD PID=222252
$$      CHANGE CSHEAR 121  NEW PID=333352   OLD PID=222252
$$      CHANGE CSHEAR 123  NEW PID=11114    OLD PID=4
$$
$$      ****************************************************************
$$      *                  VERTICAL SHEAR PANELS                       *
$$      ****************************************************************
$$
$$      CHANGE CSHEAR 247  NEW PID=3333302  OLD PID=2222302
$$      CHANGE CSHEAR 248  NEW PID=3333901  OLD PID=2222402
$$      CHANGE CSHEAR 249  NEW PID=3333901  OLD PID=2222501
$$
$$      ****************************************************************
$$      *                     HORIZONTAL RODS                          *
$$      ****************************************************************
$$
$$      CHANGE CROD 475    NEW PID=8888313  OLD PID=313
$$      CHANGE CROD 493    NEW PID=8888424  OLD PID=424
$$      CHANGE CROD 495    NEW PID=8888419  OLD PID=419
$$      CHANGE CROD 527    NEW PID=8888408  OLD PID=408
$$      CHANGE CROD 529    NEW PID=8888901  OLD PID=420
$$      CHANGE CROD 530    NEW PID=902      OLD PID=421
$$      CHANGE CROD 531    NEW PID=8888403  OLD PID=403
$$      CHANGE CROD 555    NEW PID=8888511  OLD PID=511
$$      CHANGE CROD 557    NEW PID=8888519  OLD PID=519
$$      CHANGE CROD 575    NEW PID=8888514  OLD PID=514
$$
$$      ****************************************************************
$$      *    SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE    *
$$      ****************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    99.9+9  99.9+9  99.9+9
PSHEAR  3333901 24      0.123
PROD    8888901 24      0.109
PROD    902     14      1.248
PROD    8888902 24      1.248
```

```
$$      ****************************************************************
$$      *           BULK DATA DECK FOR TEST 1 (SIMPLE DAMAGE)          *
$$      *              F-84F WING PROJECT - DAMAGED WING               *
$$      *                   MODEL B - STATIC CASE                      *
$$      *               SPARS AND RIBS:  CROD AND CSHEAR               *
$$      *                    STIFFENERS:  CROD                         *
$$      *                   SKIN PANELS:  CQDMEM                       *
$$      *             NO TORSIONAL STIFFNESS IN SPARS                  *
$$      ****************************************************************
$$
$$      ****************************************************************
$$      *                QDMEM PANELS - TOP OF WING                    *
$$      ****************************************************************
$$
$$      CHANGE CQDMEM 73   NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 75   NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 77   NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 79   NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 97   NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 101  NEW PID=9999     OLD PID=222252
$$      CHANGE CQDMEM 103  NEW PID=9999     OLD PID=222252
$$      CHANGE CQDMEM 105  NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 117  NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 119  NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 121  NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 123  NEW PID=11114    OLD PID=4
$$
$$      ****************************************************************
$$      *                  VERTICAL SHEAR PANELS                       *
$$      ****************************************************************
$$
$$      CHANGE CSHEAR 247  NEW PID=3333302  OLD PID=2222302
$$      CHANGE CSHEAR 248  NEW PID=3333901  OLD PID=2222402
$$      CHANGE CSHEAR 249  NEW PID=3333901  OLD PID=2222901
$$
$$      ****************************************************************
$$      *                     HORIZONTAL RODS                          *
$$      ****************************************************************
$$
$$      CHANGE CROD 475    NEW PID=8888431  OLD PID=431
$$      CHANGE CROD 493    NEW PID=8888127  OLD PID=127
$$      CHANGE CROD 495    NEW PID=8888108  OLD PID=108
$$      CHANGE CROD 527    NEW PID=8888810  OLD PID=810
$$      CHANGE CROD 529    NEW PID=8888901  OLD PID=832
$$      CHANGE CROD 530    NEW PID=902      OLD PID=839
$$      CHANGE CROD 531    NEW PID=8888902  OLD PID=902
$$      CHANGE CROD 555    NEW PID=8888121  OLD PID=121
$$      CHANGE CROD 557    NEW PID=8888134  OLD PID=134
$$      CHANGE CROD 575    NEW PID=8888633  OLD PID=633
$$
$$      ****************************************************************
$$      *    SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE    *
$$      ****************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    99.9+9  99.9+9  99.9+9
PSHEAR  3333901 24      0.123
PROD    8888901 24      0.109
PROD    902     14      0.890
PROD    8888902 24      0.890
```

```
$$      ***************************************************************
$$      *          BULK DATA DECK FOR TEST 1 (DETAILED DAMAGE)        *
$$      *             F-84F WING PROJECT - DAMAGED WING               *
$$      *                 MODEL D - STATIC CASE                       *
$$      *             SPARS AND RIBS:  CROD AND CSHEAR                *
$$      *                  STIFFENERS:  CROD                          *
$$      *                  SKIN PANELS:  CQDMEM                       *
$$      *              NO TORSIONAL STIFFNESS IN SPARS                *
$$      ***************************************************************
$$
$$      ***************************************************************
$$      *                CQDMEM PANELS - TOP OF WING                  *
$$      ***************************************************************
$$
$$      CHANGE CQDMEM 73   NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 75   NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 77   NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 79   NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 97   NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 101  NEW PID=9999     OLD PID=222252
$$      CHANGE CQDMEM 103  NEW PID=9999     OLD PID=222252
$$      CHANGE CQDMEM 105  NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 117  NEW PID=11112    OLD PID=2
$$      CHANGE CQDMEM 119  NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 121  NEW PID=333352   OLD PID=222252
$$      CHANGE CQDMEM 123  NEW PID=11114    OLD PID=4
$$
$$      ***************************************************************
$$      *                  VERTICAL SHEAR PANELS                      *
$$      ***************************************************************
$$
$$      THE CARDS FOR CSHEARS 247, 248, AND 249 ARE BEING REPLACED BY
$$      CARDS IN A SPECIAL SECTION TO MODEL THIS DAMAGE CASE
$$
$$      ***************************************************************
$$      *                    HORIZONTAL RODS                          *
$$      ***************************************************************
$$
$$      CHANGE CROD 475    NEW PID=8888431  OLD PID=431
$$      CHANGE CROD 493    NEW PID=8888127  OLD PID=127
$$      CHANGE CROD 495    NEW PID=8888108  OLD PID=108
$$      CHANGE CROD 527    NEW PID=8888510  OLD PID=510
$$      THE CARD FOR CRODS 529 AND 530 IS REPLACED IN THE DAMAGE SECTION
$$      CHANGE CROD 531    NEW PID=8888502  OLD PID=502
$$      CHANGE CROD 555    NEW PID=8888121  OLD PID=121
$$      CHANGE CROD 557    NEW PID=8888134  OLD PID=134
$$      CHANGE CROD 575    NEW PID=8888633  OLD PID=633
$$
$$      ***************************************************************
$$      *     SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE  *
$$      ***************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                          +M99
+M99    99.9+9  99.9+9  99.9+9
$$
$       ***************************************************************
$       *           SPECIAL CARDS FOR TEST 1 DETAILED DAMAGE          *
$       ***************************************************************
$
$       BE SURE TO ELIMINATE CARD FOR CRODS 529 & 530 IN MAIN DECK
$       AND CARDS FOR CSHEARS 247, 248, & 249
$
GRID    8085            130.9   0.0     0.0
GRID    8115            91.8    0.0     0.0
GRID    8143            54.0    0.0     0.0
GRID    8163            29.6    0.0     0.0
CROD    9475    7475    8115    8085    9575    7575    8163    8143
CROD    9529    88887529 8143   8115    530     6530    144     118
CSHEAR  8247    2222302 8115    116     86      8085
CSHEAR  9247    2222302 115     8115    8085    85
CSHEAR  8248    3333402 8143    144     116     8115
CSHEAR  8249    2222501 8163    164     144     8143
CSHEAR  9249    2222501 163     8163    8143    143
```

```
PROD    7475    13      1.51
PROD    88887475 23     1.51
PROD    7529    14      0.498
PROD    88887529 24     0.498
PROD    7575    15      1.56
PROD    88887575 25     1.56
PROD    6530    14      1.780
PROD    88886530 24     1.780
MPC     100     8163    1       +2.0    164     1       -1.0            +M8163A
+M8163A         163     1       -1.0
MPC     100     8163    2       +2.0    164     2       -1.0            +M8163B
+M8163B         163     2       -1.0
MPC     100     8163    3       +2.0    164     3       -1.0            +M8163C
+M8163C         163     3       -1.0
MPC     100     8143    1       +2.0    144     1       -1.0            +M8143A
+M8143A         143     1       -1.0
MPC     100     8143    2       +2.0    144     2       -1.0            +M8143B
+M8143B         143     2       -1.0
MPC     100     8143    3       +2.0    144     3       -1.0            +M8143C
+M8143C         143     3       -1.0
MPC     100     8115    1       +2.0    116     1       -1.0            +M8115A
+M8115A         115     1       -1.0
MPC     100     8115    2       +2.0    116     2       -1.0            +M8115B
+M8115B         115     2       -1.0
MPC     100     8115    3       +2.0    116     3       -1.0            +M8115C
+M8115C         115     3       -1.0
MPC     100     8085    1       +2.0    86      1       -1.0            +M8085A
+M8085A         85      1       -1.0
MPC     100     8085    2       +2.0    86      2       -1.0            +M8085B
+M8085B         85      2       -1.0
MPC     100     8085    3       +2.0    86      3       -1.0            +M8085C
+M8085C         85      3       -1.0
$
```

```
$$      ************************************************************
$$      *               BULK DATA DECK FOR TEST 2C                 *
$$      *          F-84F WING PROJECT - DAMAGED WING               *
$$      *               MODEL A - STATIC CASE                      *
$$      *            SPARS AND RIBS   CROD AND CSHEAR              *
$$      *                STIFFENERS   CROD                         *
$$      *                SKIN PANELS:  CSHEAR                      *
$$      *           NO TORSIONAL STIFFNESS IN SPARS                *
$$      ************************************************************
$$
$$      ************************************************************
$$      *               SHEAR PANELS - TOP OF WING                 *
$$      ************************************************************
$$
$$      CHANGE CSHEAR 83  NEW PID=9999   OLD PID=222252
$$      CHANGE CSHEAR 84  NEW PID=11112  OLD PID=2
$$
$$      ************************************************************
$$      *                 VERTICAL SHEAR PANELS                    *
$$      ************************************************************
$$
$$      CHANGE CSHEAR 237  NEW PID=9999  OLD PID=2222401
$$
$$      ************************************************************
$$      *                    HORIZONTAL RODS                       *
$$      ************************************************************
$$
$$      CHANGE CROD 509  NEW PID=9999     OLD PID=416
$$      CHANGE CROD 510  NEW PID=9999     OLD PID=417
$$      CHANGE CROD 511  NEW PID=8888402  OLD PID=409
$$
$$      ************************************************************
$$      *    SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE  *
$$      ************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    99.9+9  99.9+9  99.9+9
```

```
$$      ************************************************************
$$      *               BULK DATA DECK FOR TEST 2C                 *
$$      *          F-84F WING PROJECT - DAMAGED WING               *
$$      *               MODEL C - STATIC CASE                      *
$$      *            SPARS AND RIBS:  CROD AND CSHEAR              *
$$      *                STIFFENERS:  CROD                         *
$$      *                SKIN PANELS:  CODMEM                      *
$$      *           NO TORSIONAL STIFFNESS IN SPARS                *
$$      ************************************************************
$$
$$      ************************************************************
$$      *               QDMEM PANELS - TOP OF WING                 *
$$      ************************************************************
$$
$$      CHANGE CODMEM 83  NEW PID=9999   OLD PID=222252
$$      CHANGE CODMEM 84  NEW PID=11112  OLD PID=2
$$
$$      ************************************************************
$$      *                 VERTICAL SHEAR PANELS                    *
$$      ************************************************************
$$
$$      CHANGE CSHEAR 237  NEW PID=9999  OLD PID=2222401
$$
$$      ************************************************************
$$      *                    HORIZONTAL RODS                       *
$$      ************************************************************
$$
$$      CHANGE CROD 509  NEW PID=9999     OLD PID=525
$$      CHANGE CROD 510  NEW PID=9999     OLD PID=518
$$      CHANGE CROD 511  NEW PID=8888901  OLD PID=506
$$
$$      ************************************************************
$$      *    SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE  *
$$      ************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    99.9+9  99.9+9  99.9+9
PROD    8888901 25      0.48
```

```
$$      ************************************************************
$$      *                 BULK DATA DECK FOR TEST 3B               *
$$      *           F-84F WING PROJECT - DAMAGED WING              *
$$      *                 MODEL A - STATIC CASE                    *
$$      *             SPARS AND RIBS:  CROD AND CSHEAR             *
$$      *                    STIFFENERS:  CROD                     *
$$      *                   SKIN PANELS:  CSHEAR                   *
$$      *             NO TORSIONAL STIFFNESS IN SPARS              *
$$      ************************************************************
$$
$$      ************************************************************
$$      *              SHEAR PANELS - BOTTOM OF WING               *
$$      ************************************************************
$$
$$      CHANGE CSHEARS 102 AND 104  NEW PID=9999  OLD PID=222252
$$      CHANGE CSHEARS 106 AND 108  NEW PID=9999  OLD PID=2
$$
$$      ************************************************************
$$      *                  VERTICAL SHEAR PANELS                   *
$$      ************************************************************
$$
$$      CHANGE CSHEAR 237  NEW PID=1111901  OLD PID=2222401
$$      CHANGE CSHEAR 243  NEW PID=111115   OLD PID=15
$$      CHANGE CSHEAR 248  NEW PID=3333902  OLD PID=2222402
$$      CHANGE CSHEAR 256  NEW PID=11112    OLD PID=2
$$
$$      ************************************************************
$$      *                     HORIZONTAL RODS                      *
$$      ************************************************************
$$
$$      CHANGE CROD 509  NEW PID=901       OLD PID=416
$$      CHANGE CROD 510  NEW PID=8888902   OLD PID=417
$$      CHANGE CROD 527  NEW PID=903       OLD PID=406
$$      CHANGE CROD 528  NEW PID=8888904   OLD PID=405
$$      CHANGE CROD 529  NEW PID=905       OLD PID=420
$$      CHANGE CROD 530  NEW PID=8888906   OLD PID=421
$$
$$      ************************************************************
$$      *     SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE    *
$$      ************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    9.99+9  9.99+9  9.99+9
PROD    901     14      0.849
PROD    8888901 24      0.849
PROD    8888902 24      0.228
PROD    903     14      0.866
PROD    8888903 24      0.866
PROD    8888904 24      0.489
PROD    905     14      4.084
PROD    8888905 24      4.084
PROD    8888906 24      1.868
PSHEAR  1111901 94      0.200
PSHEAR  3333901 95      0.200
PSHEAR  3333902 24      0.246
MAT1    94      10.3+6  3.9+6           3.14-3                  +M94
+M94    3.08+4  5.39+4  2.83+4
MAT1    95      7.79+6  3.9+6           3.14-3                  +M95
+M95    3.08+4  6.41+4  2.77+4
```

```
$$      ************************************************************
$$      *                 BULK DATA DECK FOR TEST 3B               *
$$      *           F-84F WING  PROJECT - DAMAGED WING             *
$$      *                 MODEL C - STATIC CASE                    *
$$      *             SPARS AND RIBS:  CROD AND CSHEAR             *
$$      *                    STIFFENERS:  CROD                     *
$$      *                   SKIN PANELS:  CODMEM                   *
$$      *             NO TORSIONAL STIFFNESS IN SPARS              *
$$      ************************************************************
$$
$$      ************************************************************
$$      *              CODMEM PANELS - BOTTOM OF WING              *
$$      ************************************************************
$$
$$      CHANGE CODMEMS 102 AND 104  NEW PID=9999  OLD PID=222252
$$      CHANGE CODMEMS 106 AND 108  NEW PID=9999  OLD PID=2
$$
$$      ************************************************************
$$      *                  VERTICAL SHEAR PANELS                   *
$$      ************************************************************
$$
$$      CHANGE CSHEAR 237  NEW PID=1111901  OLD PID=2222401
$$      CHANGE CODMEM 243  NEW PID=111115   OLD PID=15
$$      CHANGE CSHEAR 248  NEW PID=3333902  OLD PID=2222402
$$      CHANGE CODMEM 256  NEW PID=11112    OLD PID=2
$$
$$      ************************************************************
$$      *                     HORIZONTAL RODS                      *
$$      ************************************************************
$$
$$      CHANGE CROD 509  NEW PID=901       OLD PID=416
$$      CHANGE CROD 510  NEW PID=8888902   OLD PID=417
$$      CHANGE CROD 527  NEW PID=903       OLD PID=510
$$      CHANGE CROD 528  NEW PID=8888904   OLD PID=511
$$      CHANGE CROD 529  NEW PID=905       OLD PID=532
$$      CHANGE CROD 530  NEW PID=8888906   OLD PID=539
$$
$$      ************************************************************
$$      *     SPECIAL PROPERTY AND MATERIAL CARDS FOR INITIAL DAMAGE    *
$$      ************************************************************
$$
MAT1    99      10.0    5.0             3.14-3                  +M99
+M99    99.9+9  99.9+9  99.9+9
PROD    901     14      0.849
PROD    8888901 24      0.849
PROD    8888902 24      0.228
PROD    903     14      0.866
PROD    8888903 24      0.866
PROD    8888904 24      0.489
PROD    905     14      4.084
PROD    8888905 24      4.084
PROD    8888906 24      1.868
PSHEAR  1111901 94      0.200
PSHEAR  3333901 95      0.200
PSHEAR  3333902 24      0.246
MAT1    94      10.3+6  3.9+6           3.14-3                  +M94
+M94    3.08+4  5.39+4  2.83+4
MAT1    95      7.79+6  3.9+6           3.14-3                  +M95
+M95    3.08+4  6.41+4  2.77+4
```

APPENDIX H

PROGRESSIVE STRUCTURAL COLLAPSE ANALYSIS LISTING

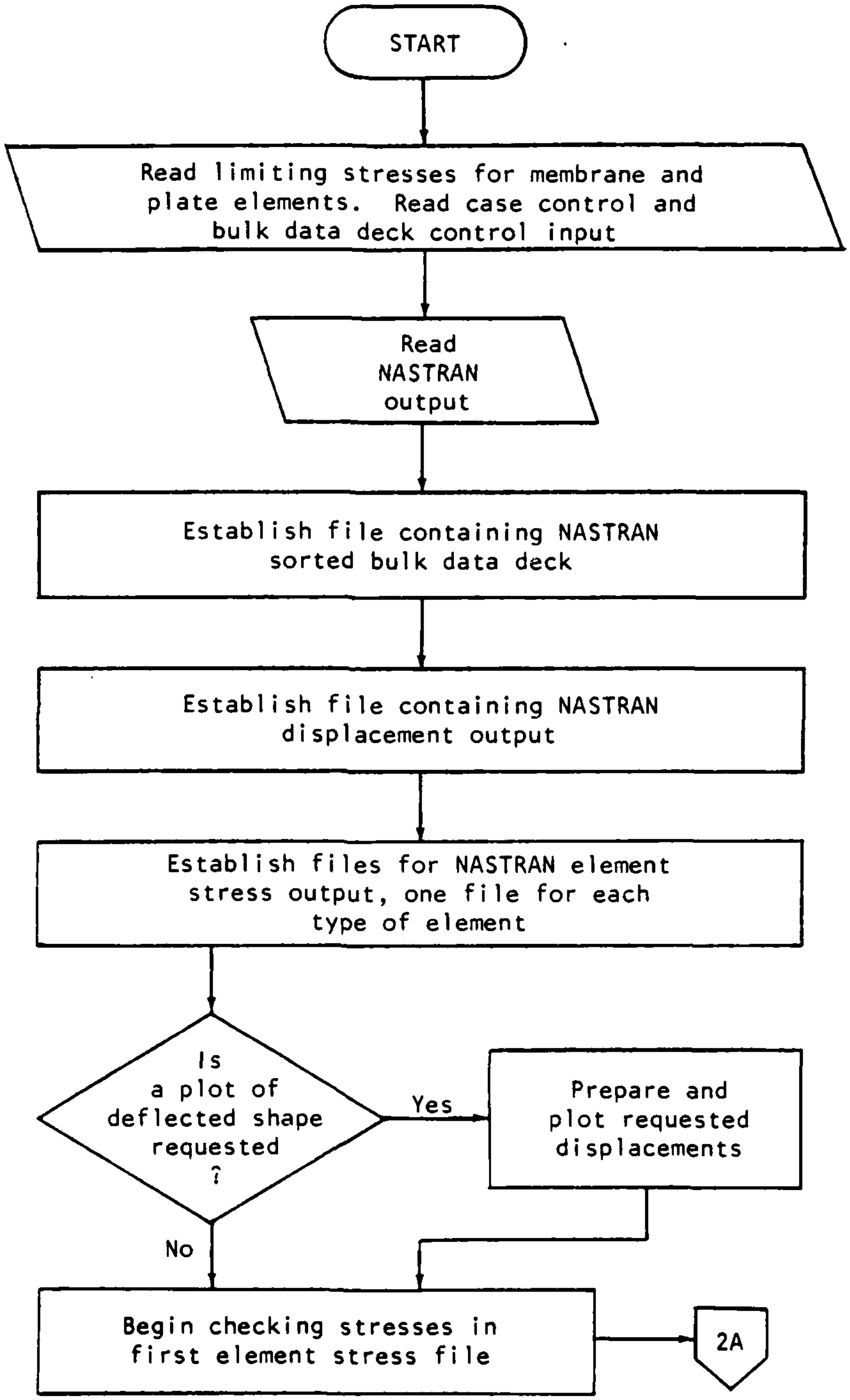

Figure 25. PROSCAN Functional Flow Diagram

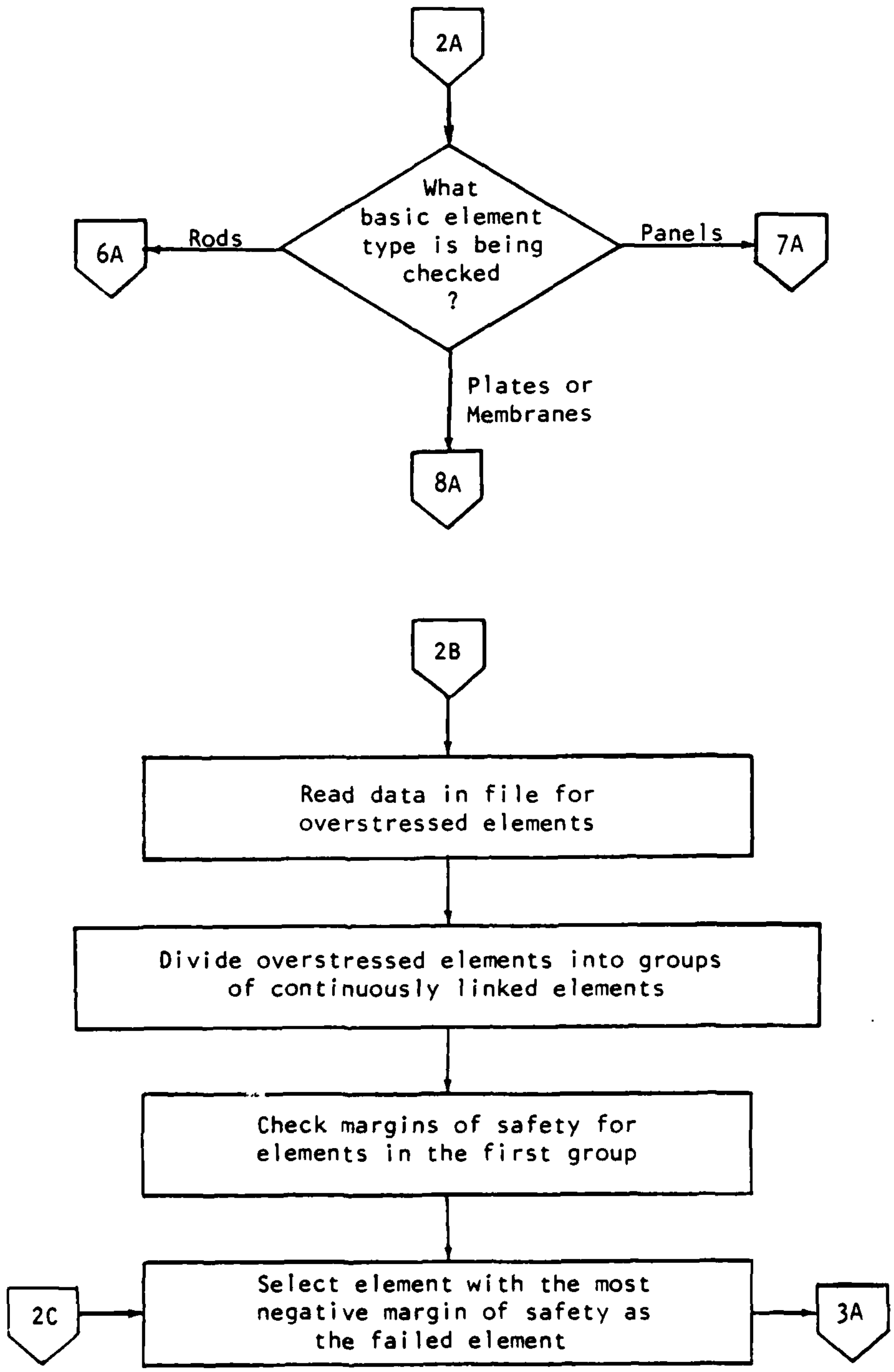

Figure 25. (Continued)

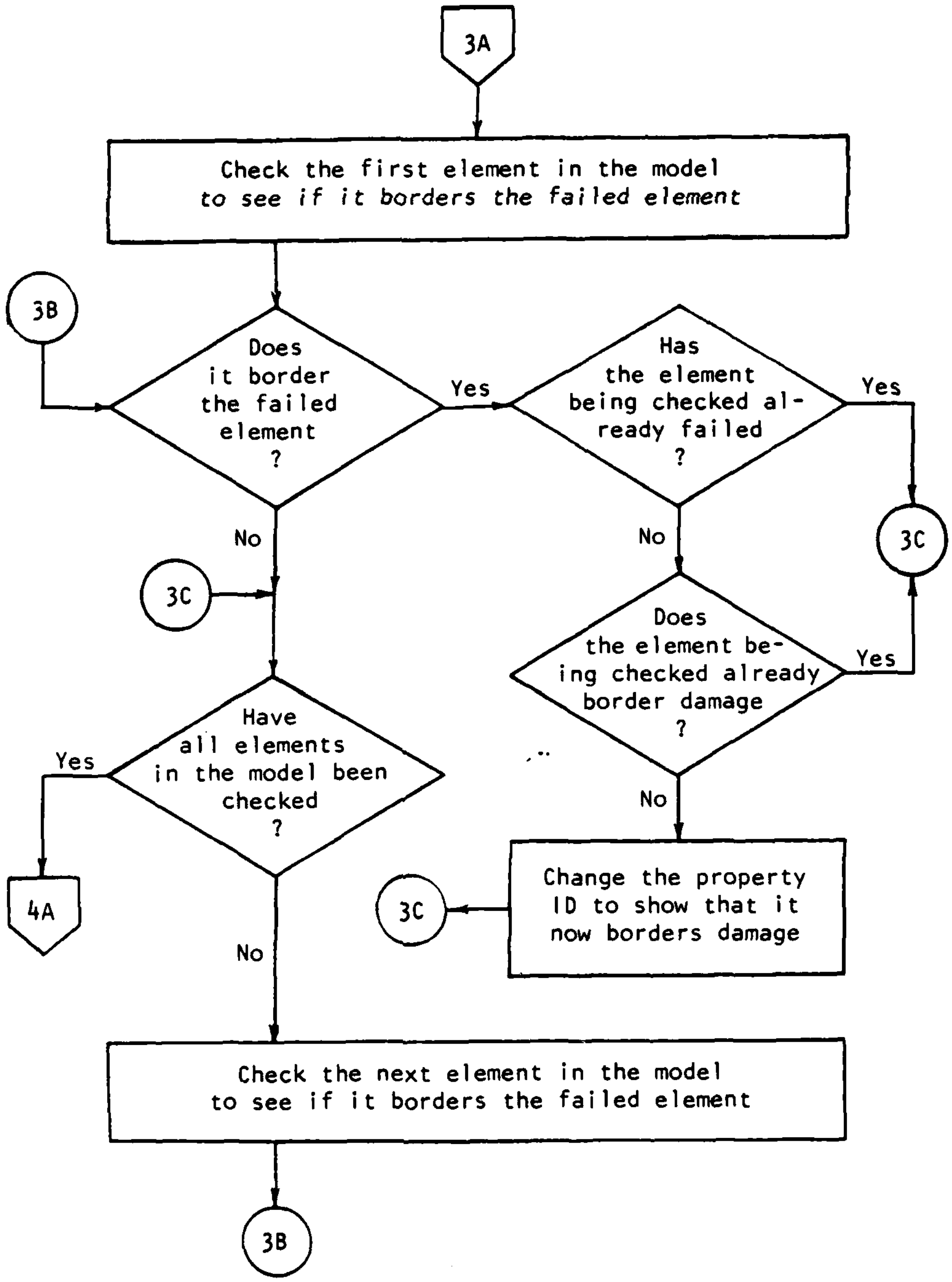

Figure 25. (Continued)

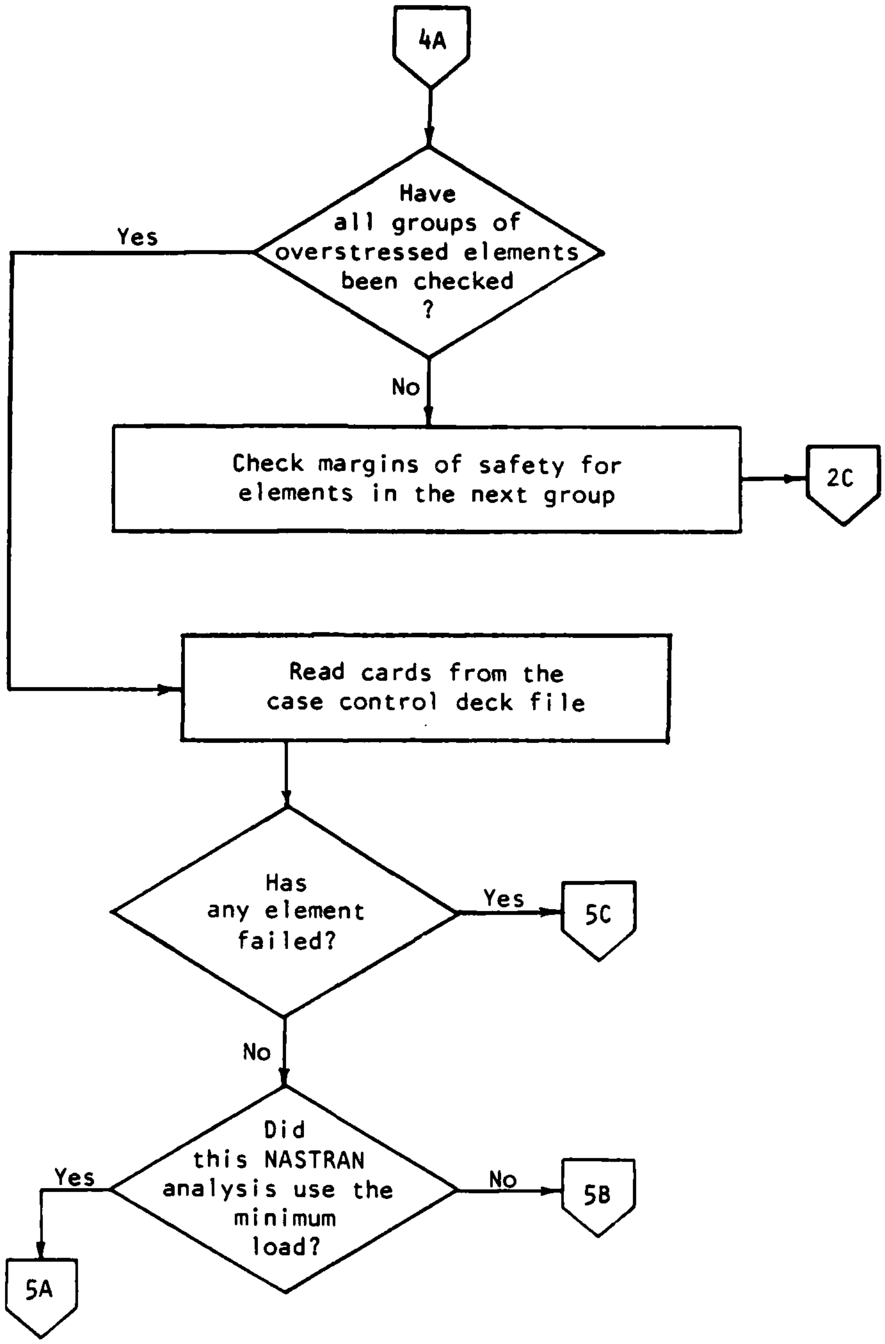

Figure 25. (Continued)

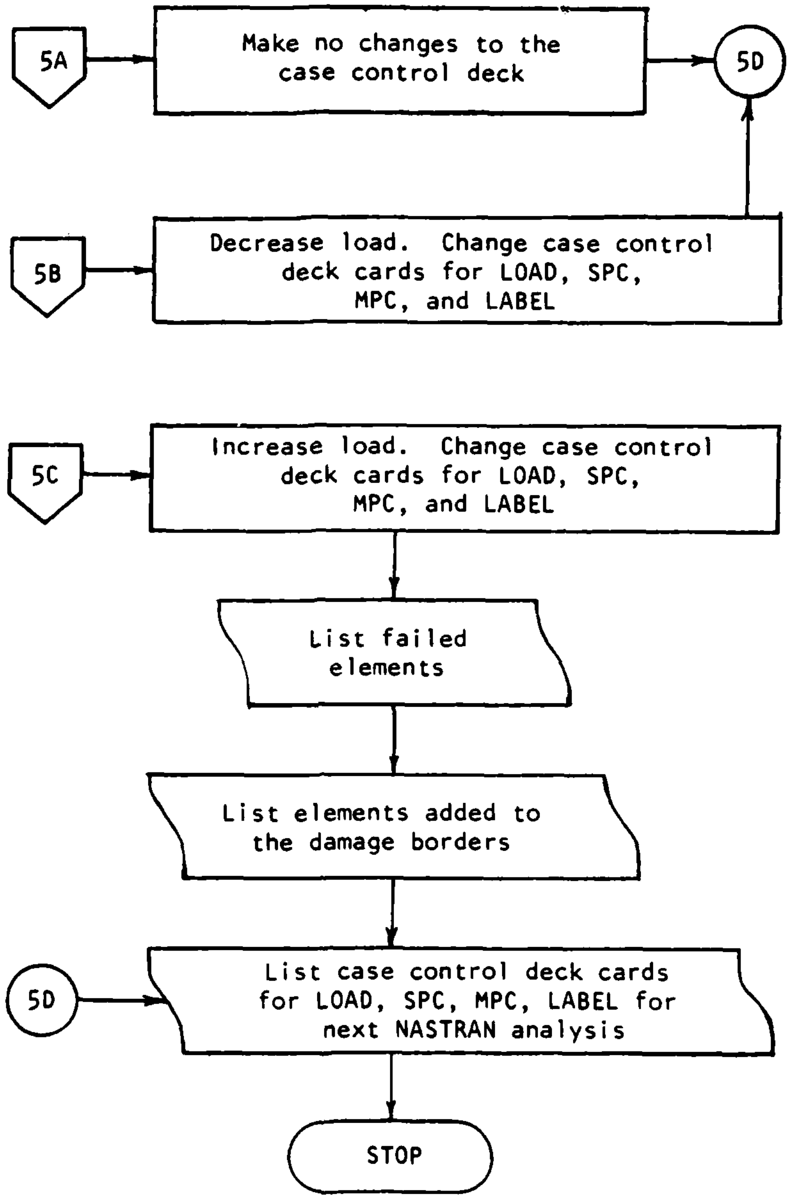

Figure 25. (Continued)

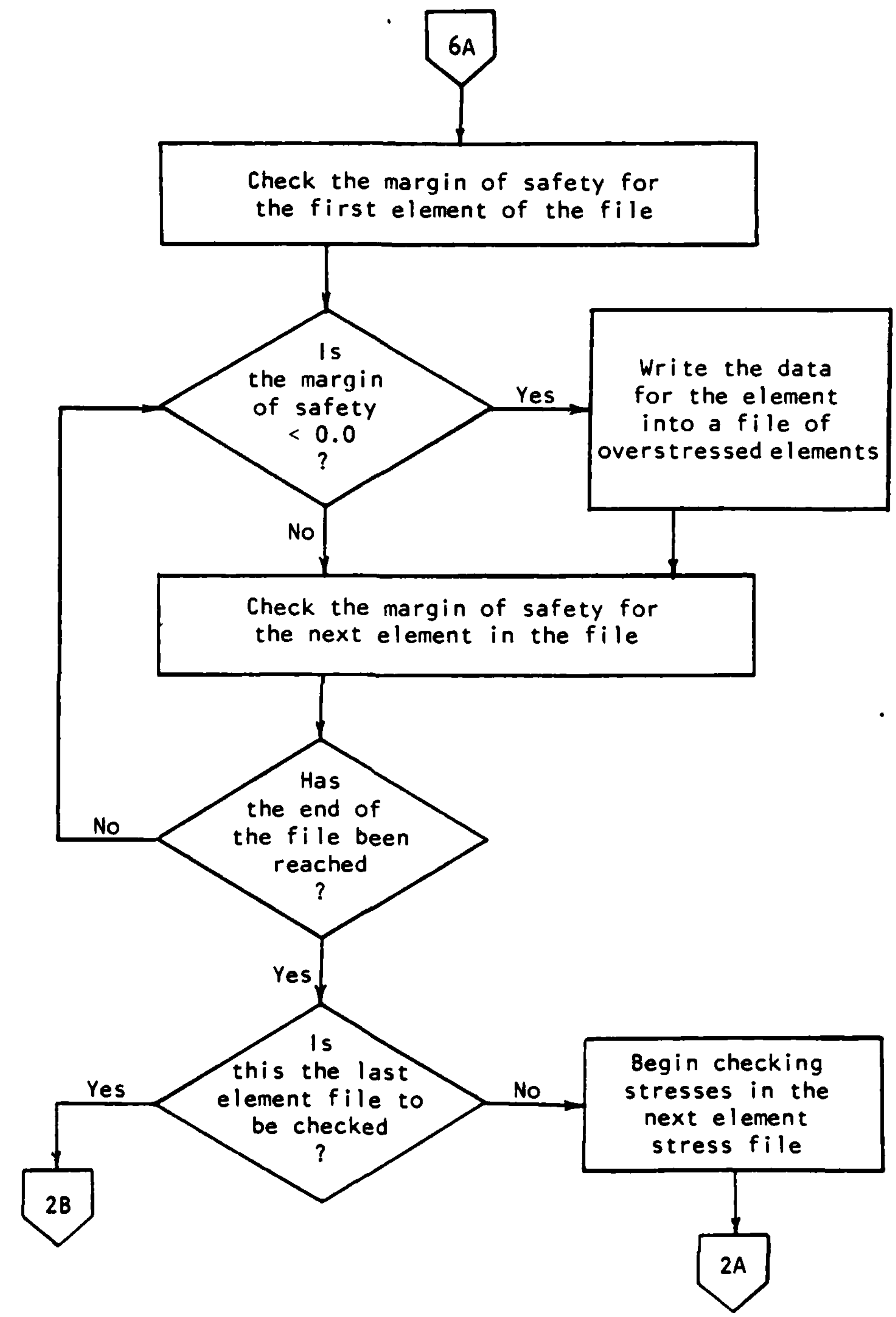

Figure 25. (Continued)

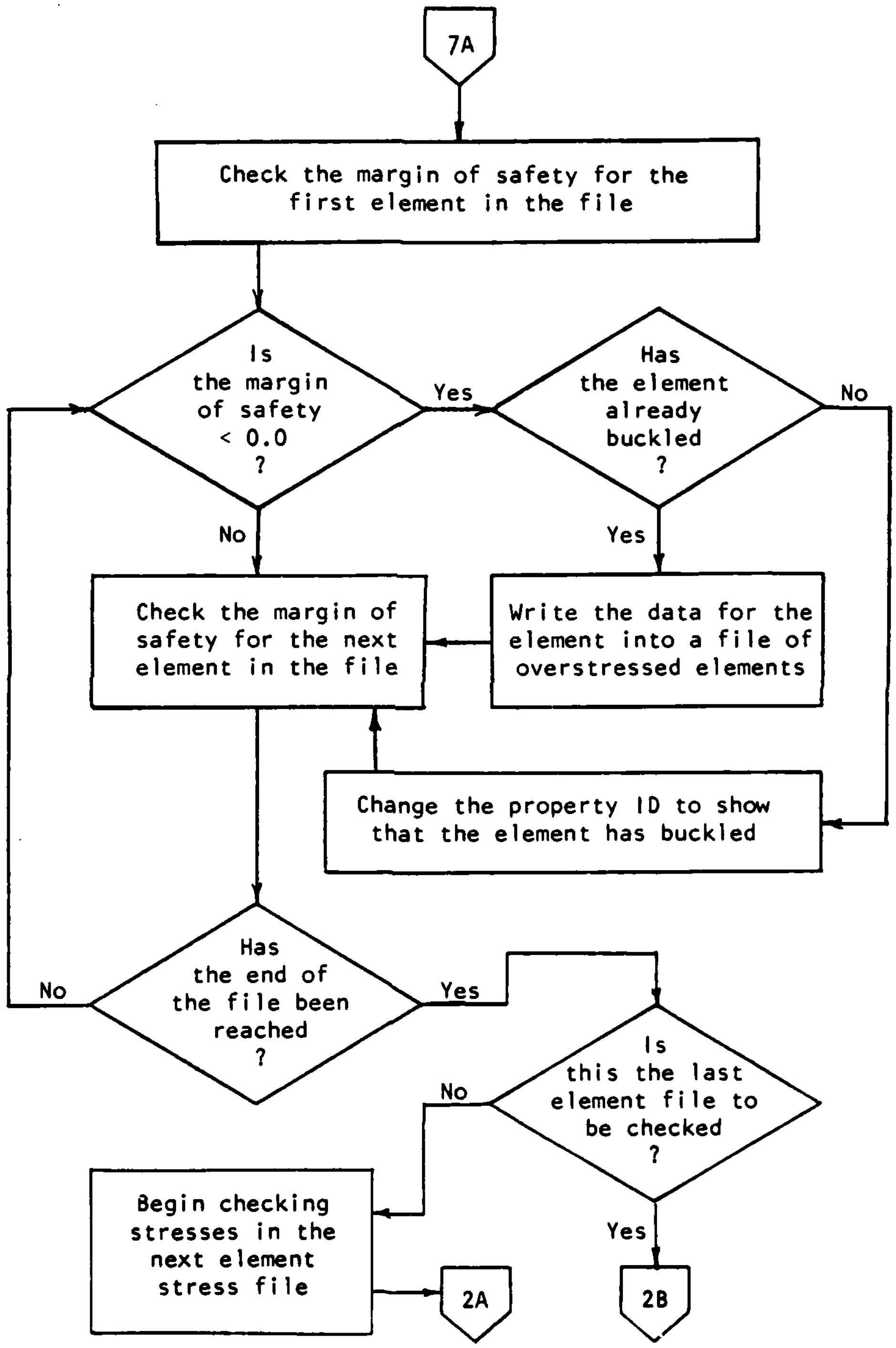

Figure 25. (Continued)

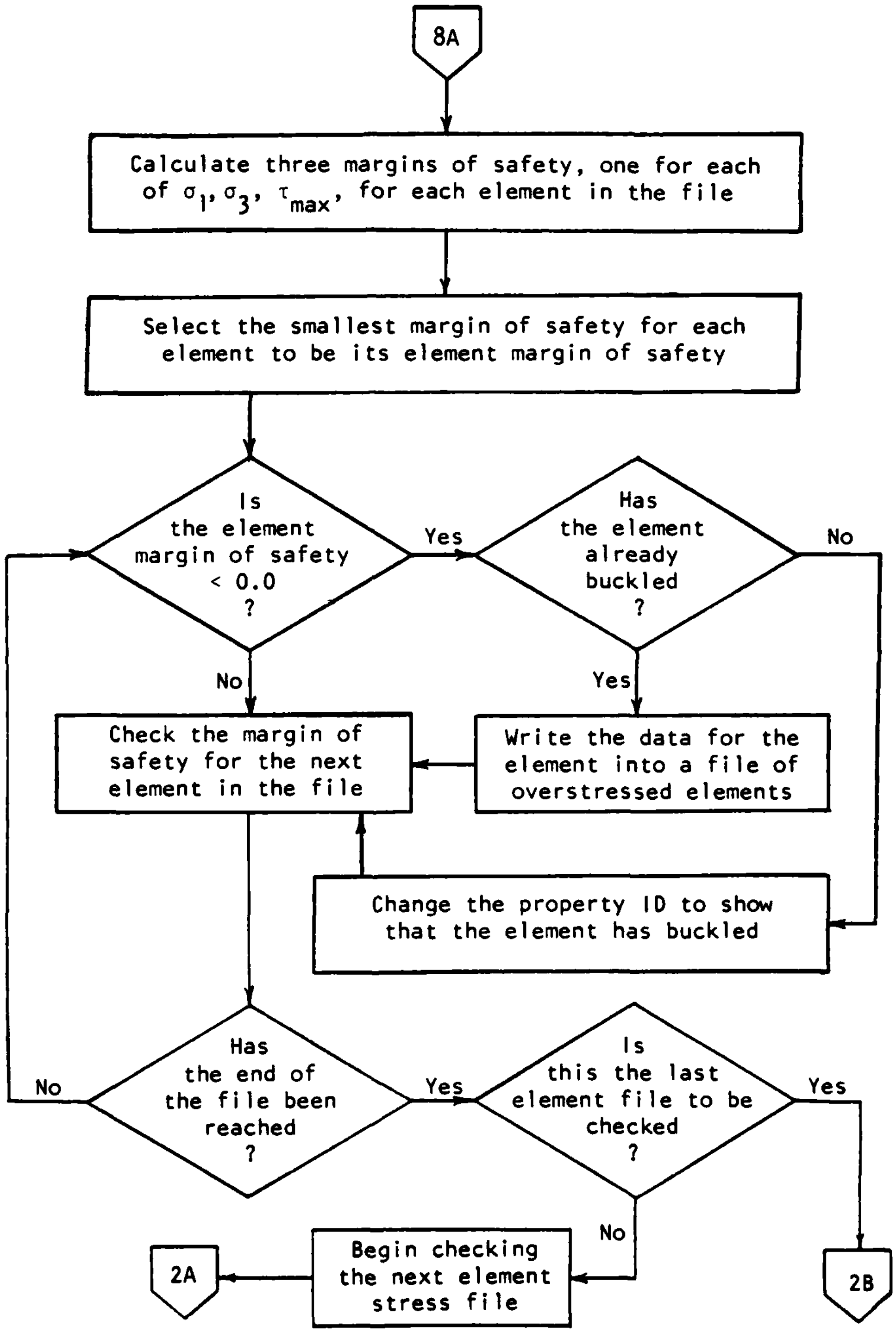

Figure 25. (Continued)

```
C
C     ***********************************************************************
C     *     PROSCAN (PROGRESSIVE STRUCTURAL COLLAPSE ANALYSIS) WAS           *
C     *     DEVELOPED IN 1982 FOR THE JOINT TECHNICAL COORDINATING           *
C     *     GROUP (SUBGROUP FOR MUNITIONS EFFECTIVENESS AND AERIAL           *
C     *     TARGET VULNERABILITY) BY G.E. RIGGS FOR THE PROGRESSIVE          *
C     *     COLLAPSE ANALYSIS OF DAMAGED AIRCRAFT WING STRUCTURES.           *
C     *     THIS VERSION OF THE PROGRAM WAS COMPLETED 31 AUGUST 1982         *
C     ***********************************************************************
C
      COMMON / BULKDK / CARD1,CARD2,CARD3,CARD4,PIDF,PIDO,PID1,PID2,PID3
      COMMON / CSCTL1 / LOADS, ISPC, IMPC, ILBL
      COMMON / CSCTL2 / XLOAD(40),XSPC(40),XMPC(40),XLBL(20,18)
      COMMON / CTLDTA / LTYPE(18), NUM(18)
      COMMON / CTLRD1 / ICNTF2, ICNTGF, ICNTSF, NBULK, NDISPN, NGDN
      COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
      COMMON / DTANAS / STRE, SUBC1, SUBC2
      COMMON / MATIDS / XMIDO, XMIDF
      COMMON / TEMPRT / IPSW
      COMMON / TITLE  / RUN(72)
      COMMON / UNITS1 / LU1, LU2, LU3, LU4, LUNAS, IR
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      COMMON / UNITS3 / LUC1, LUC2, LUD1, LUD2
C     ARRAYS  STRMEM(3,4)  &  STRPLT(3,4)
C     PIDT      PID1T      PID2T      PID3T
C     PIDC      PID1C      PID2C      PID3C
C     PIDS      PID1S      PID2S      PID3S
C     PID  IS UNBUCKLED AWAY FROM DAMAGE
C     PID1 IS UNBUCKLED BORDERING DAMAGE
C     PID2 IS   BUCKLED AWAY FROM DAMAGE
C     PID3 IS   BUCKLED BORDERING DAMAGE
          REWIND IR
          PRINT 1095
          READ 1010, RUN
          PRINT 1100, RUN
          READ 1000, NBULK, NSUB, NDISPN, NGDN, IPSW
          READ 1000, NFS, IFLAG, ICNTF2, ICNTSF, ICNTGF
          READ 1000, IBOTH, IMEM, IPLT, IFCON
          IF ( ICNTSF .EQ. 1 ) READ 1005, (NUMBR(I), I=1,8)
          IF ( IBOTH .EQ. 0 ) GO TO 96
      DO 90 I = 1, 4
   90     READ 2000, (STRMEM(J,I), J = 1, 3 )
      DO 92 I = 1, 3
      DO 92 J = 1, 4
   92             STRPLT(I,J) = STRMEM(I,J)
      GO TO 99
   96     IF ( IMEM .EQ. 0 ) GO TO 94
      DO 93 I = 1, 4
   93     READ 2000, ( STRMEM(J,I), J = 1, 3 )
   94     IF ( IPLT .EQ. 0 ) GO TO 99
      DO 95 I = 1, 4
   95     READ 2000, ( STRPLT(J,I), J = 1, 3 )
   99     READ 1000, LOADS, ISPC, IMPC, ILBL
                 NLOADS = 2 * LOADS
          READ 1007, ( XLOAD(I), I = 1, NLOADS )
          IF ( ISPC .EQ. 0 ) GO TO 100
          READ 1007, ( XSPC(I), I = 1, NLOADS )
  100 CONTINUE
          IF ( IMPC .EQ. 0 ) GO TO 110
          READ 1007, ( XMPC(I), I = 1, NLOADS )
  110 CONTINUE
          IF ( ILBL .EQ. 0 ) GO TO 140
      DO 120 I = 1, LOADS
  120     READ 1003, ( XLBL(I,J), J = 1, 18 )
  140 CONTINUE
          IF ( IPSW .GT. 0 ) PRINT 9003, IPSW
 9003 FORMAT (///,'0<<<<<  INTERMEDIATE PRINT LEVEL IS',I2,'  >>>>>')
          PRINT 1011
          PRINT 1015
          IF ( ICNTF2 .EQ. 1 )   GO TO 160
          PRINT 1020
      GO TO 180
  160     PRINT 1025
  180     PRINT 1030
          IF ( ICNTSF .EQ. 1 ) GO TO 200
          PRINT 1020
      GO TO 220
  200     PRINT 1025
  220     PRINT 1038
          IF ( ICNTGF .EQ. 1 ) GO TO 240
          PRINT 1020
      GO TO 260
  240     PRINT 1035
  260     PRINT 1040
          IF ( NGDN .EQ. 0 ) GO TO 280
          PRINT 1045
      GO TO 300
  280     PRINT 1050
  300     IF ( NFS .EQ. 0 ) GO TO 340
          PRINT 1055
          PRINT 1065
          IF ( IFLAG .EQ. 1 ) GO TO 320
          PRINT 1070
      GO TO 360
  320     PRINT 1075
      GO TO 360
  340     PRINT 1060
  360     PRINT 1080
          PRINT 1085, NSUB, NDISPN, NGDN
          IF ( IBOTH .EQ. 0  .AND.  IMEM .EQ. 0 ) GO TO 365
          PRINT 1190
          PRINT 1192
          PRINT 1193, ( STRMEM(J,1), J = 1, 3 )
          PRINT 1194, ( STRMEM(J,2), J = 1, 3 )
          PRINT 1195, ( STRMEM(J,3), J = 1, 3 )
          PRINT 1196, ( STRMEM(J,4), J = 1, 3 )
  365     IF ( IBOTH .EQ. 0  .AND.  IPLT .EQ. 0 ) GO TO 370
          PRINT 1191
          PRINT 1192
          PRINT 1193, ( STRPLT(J,1), J = 1, 3 )
          PRINT 1194, ( STRPLT(J,2), J = 1, 3 )
          PRINT 1195, ( STRPLT(J,3), J = 1, 3 )
          PRINT 1196, ( STRPLT(J,4), J = 1, 3 )
  370 CONTINUE
          PRINT 1095
          PRINT 1096
          PRINT 1097, ( XLOAD(I), I = 1, NLOADS )
          IF ( ISPC .NE. 0 ) PRINT 1098, ( XSPC(I), I = 1, NLOADS )
          IF ( IMPC .NE. 0 ) PRINT 1093, ( XMPC(I), I = 1, NLOADS )
          IF ( ILBL .EQ. 0 ) GO TO 400
          PRINT 1094, ( XLBL(1,K), K = 1, 18 )
      DO 380 I = 2, LOADS
  380     PRINT 1099, ( XLBL(I,K), K = 1, 18 )
  400 CONTINUE
          READ 1004, CARD1, CARD2, CARD3, CARD4
          READ 1006, PIDF, PIDO
          READ 1006, PID1, PID2, PID3
          PRINT 1101, PIDF, PIDO, PID1, PID2, PID3
          IF ( IFCON .EQ. 0 ) GO TO 420
          READ 1006, XMIDF, XMIDO
          PRINT 1197, XMIDF, XMIDO
  420 CONTINUE
          PRINT 1102, CARD1, CARD2
          PRINT 1103, CARD3, CARD4
          IF ( IPSW .GT. 3 ) PRINT 9001
 9001 FORMAT('0<<< CALL SUBROUTINE MAIND FROM MAIN >>>')
      CALL MAIND
          IF ( IPSW .GT. 3 ) PRINT 9002
 9002 FORMAT('0<<< RETURN TO MAIN FROM SUBROUTINE MAIND >>>')
          PRINT 1110
      STOP
 1000 FORMAT(8I5)
 1001 FORMAT(1H0,8I5)
 1002 FORMAT ( 7( 2A4, 2X ) )
 1003 FORMAT ( 18A4 )
 1004 FORMAT ( 5A4,4X,1A4 )
 1005 FORMAT(8I5)
 1006 FORMAT ( 4(1A4,4X) )
 1007 FORMAT ( 18A4, /, 18A4 )
 2000 FORMAT(8E10.3)
 2001 FORMAT(1H0, 8F10.4)
 1010 FORMAT(80A1)
```

```
1011 FORMAT(///,'0* * * * *   P R O G R A M   C O N T R O L   E C H O',
     *      '  * * * * * *')
1015 FORMAT( 1H0, 12X, 'DISPLACEMENT FILE STATUS: ')
1020 FORMAT( 1H+, 40X, 'TO BE CREATED DURING THIS RUN')
1025 FORMAT( 1H+, 40X, 'CREATED IN A PREVIOUS RUN OR PROGRAM')
1030 FORMAT( 1H0, 12X, 'STRESS FILE STATUS:')
1035 FORMAT( 1H0, 12X, 'GRID POINT FILE STATUS.')
1040 FORMAT( 1H0, 12X, 'PROGRAM FUNCTIONS:  PRINTER PLOTS PROCESSED--',
     *5X,'.',5X,'STRESS CHECKS MADE--')
1045 FORMAT( 1H+,58X,'YES')
1050 FORMAT( 1H+,58X,'NO')
1055 FORMAT( 1H+,90X,'YES')
1065 FORMAT( 1H0, 12X,'STRESS CHECK DISPOSITION: ')
1060 FORMAT( 1H+,90X,'NO')
1070 FORMAT( 1H+,39X,'CHECKED UNTIL A SUBCASE WITHOUT ELEMENT ',
     *'FAILURE IS FOUND')
1075 FORMAT( 1H+,39X,'CHECKED IN ALL SUBCASES')
1080 FORMAT(///,'0* * * * *   P R O G R A M   D A T A   E C H O' ,
     *      '  * * * * * * ')
1085 FORMAT( 1H0, 12X, 'NUMBER OF SUBCASES    ',I5,
     *//,13X,'NUMBER OF NODES IN DISPLACEMENT FILE ',I7,
     *//,13X,'NUMBER OF NODES IN GRID POINT FILE ',I9)
1090 FORMAT( 1H0, 12X,'LIMITING NORMAL STRESSES ',4X,6(2PE15.3) )
1093 FORMAT (13X,'MPC   CARD SEQUENCE ',9(2X,2A4),/,33X,9(2X,2A4),/)
1094 FORMAT ( 13X, 'LABEL CARD SEQUENCE   ',18A4 )
1095 FORMAT( 1H1, /////////////)
1096 FORMAT ( 9(2H *),'  N A S T R A N   C A S E   C O N T R O L  ',
     *  ' A N D   B U L K   D A T A   D E C K   I N P U T ',9(2H *),/)
1097 FORMAT (13X,'LOAD  CARD SEQUENCE ', 9(2X,2A4),/,33X,9(2X,2A4),/)
1098 FORMAT (13X,'SPC   CARD SEQUENCE ', 9(2X,2A4),/,33X,9(2X,2A4),/)
1099 FORMAT ( 35X, 18A4 )
1100 FORMAT(13X,' P R O B L E M   I D E N T I F I C A T I O N   ',
     *         72A1 )
1101 FORMAT (/,13X,'PROPERTY IDENTIFICATION PREFIXES:',/,35X,'FOR ',
     *'FAILED ELEMENTS ',16X,1A4,/,35X,'FOR 1-D ELEMENTS BORDERING ',
     *'DAMAGE    ',1A4,/,35X,'FOR 2-D ELEMENTS:',/,42X,'UNBUCKLED ',
     *'BORDERING DAMAGE    ',1A4,/,42X,'BUCKLED AWAY FROM DAMAGE:    ',
     *1A4,/,42X,'BUCKLED BORDERING DAMAGE      ',1A4)
1102 FORMAT (/,13X,'FIRST CONNECTIVITY CARD IN SORTED BULK DATA DECK',
     *         ' I5 ', 2A4 )
1103 FORMAT (13X,'LAST  CONNECTIVITY CARD IN SORTED BULK DATA DECK',
     *         ' I5 ', 2A4 )
1110 FORMAT (1H1,///////,10X,'END OF RSCAN PROGRAM EXECUTION.')
1190 FORMAT (1H0,12X,'LIMITING STRESSES FOR MEMBRANE ELEMENTS ')
1191 FORMAT (1H0,12X,'LIMITING STRESSES FOR PLATE ELEMENTS:')
1192 FORMAT (1H+,55X,'TENS ',8X,'COMP ',8X,'SHEAR')
1193 FORMAT (15X,'UNBUCKLED ELEMENTS AWAY FROM DAMAGE ', 3(2PE13.3) )
1194 FORMAT (15X,'UNBUCKLED ELEMENTS BORDERING DAMAGE:', 3(2PE13.3) )
1195 FORMAT (15X,'  BUCKLED ELEMENTS AWAY FROM DAMAGE:', 3(2PE13.3) )
1196 FORMAT (15X,'  BUCKLED ELEMENTS BORDERING DAMAGE:', 3(2PE13.3) )
1197 FORMAT (/,13X,'CONROD MATERIAL IDENTIFICATION NUMBERS:',/,
     *         35X,'FOR FAILED ELEMENTS ',16X,1A4,/,35X,'FOR ELEMENTS ',
     *         'BORDERING DAMAGE ',6X,1A4)
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE MAIND
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C     TABLE OF VARIABLES.
C
C     CARD(20)  - TITLE CARDS INPUT ARRAY
C     X(16)     - ARRAY USED TO READ IN REAL DATA FOR EACH ELEMENT TYPE
C     NUMSUB    - SUBCASE NO. TO BE PROCESSED
C     ITYPE     - ELEMENT TYPE IDENTIFICATION; READ FROM TITLE DATA
C     LTYPE(18) - ARRAY AGAINST WHICH ITYPE IS CHECKED
C     NTYPE     - SUBSCRIPT NO. ASSOCIATED WITH LTYPE
C     NUM(8)    - ARRAY CONTAINING NO. OF X VALUES TO BE READ FOR EACH
C                 ELEMENT TYPE
C     NUMBR(8)  - ARRAY CONTAINING NO. OF ELEMENTS IN EACH GROUP
C     STRESS    - FAILURE STRESS VALUE USED IN FAILURE SEARCHES
C     TYPE      - ALPHANUMERIC ARRAY CONTAINING TYPE PF ELEMENT WHICH
C                 IS TO BE DISPLAYED AS PART OF A GROUP OF ELEMENTS
C     LID       - ARRAY OF ELEMENT ID NOS. TO BE DISPLAYED AS A GROUP
C
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
      COMMON / CTLDTA / LTYPE(18), NUM(18)
      COMMON / CTLRD1 / ICNTF2, ICNTGF, ICNTSF, NBULK, NDISPN, NGDN
      COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
      COMMON / DTANAS / STRE, SUBC1, SUBC2
      COMMON / GRIDPT / KODE, ID(8)
      COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
      COMMON / TEMPRT / IPSW
      COMMON / UNITS1 / LU1, LU2, LU3, LU4, LUNAS, IR
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      COMMON / UNITS3 / LUC1, LUC2, LUD1, LUD2
      DIMENSION TYPE(100), LID(100)
      DIMENSION FIELD( 1 )
      INTEGER OK / 0 /
      DATA BLANK, TITL, ENDD, ATA / 4H    , 4HSTIT, 4HENDD, 4HATA  /
         IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT (1H1,'<<<<< ENTRY SUBROUTINE MAIND >>>>>')
              IBULK = LUB1
              ICSDK = LUC1
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     SEPARATE BULK DATA DECK FROM NASTRAN DISPLACEMENT & STRESS OUTPUT
              N = NBULK - 5
      DO 3  I = 1, N
         READ (LUNAS,1000) CARD
         WRITE (LUB1,1000) CARD
    3 CONTINUE
    4    READ (LUNAS,1000) CARD
         IF ( CARD(1) .EQ. TITL )  GO TO 5
         WRITE (LUB1,1000) CARD
      GO TO 4
    5    WRITE (LUB1,1000) ENDD,ATA
         BACKSPACE LUNAS
    6    READ (LUNAS,1000,END=7) CARD
         WRITE (LU1,1000) CARD
      GO TO 6
    7 CONTINUE
         REWIND LUNAS
         REWIND LUB1
         REWIND LU1
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     READ & TRANSLATE NASTRAN DISPLACEMENT OUTPUT
         IF ( NGDN .NE. 0 )  GO TO 1
         IF ( ICNTSF .EQ. 1 )  GO TO 85
         IF ( NDISPN .EQ. 0 )  GO TO 39
            N = NSUB * ( 2 * NDISPN + 6 )
         IF ( IPSW .GT. 3 ) PRINT 90001
90001 FORMAT ('0< < < READ AND TRANSLATE NASTRAN DISPLACEMENT OUTPUT')
90002 FORMAT ('0< < <       CARD = ',20A4 )
      DO 2 I = 1,N
         READ(LU1,1000)  CARD
    2 CONTINUE
      GO TO 39
    1    IF ( ICNTF2 .EQ. 1 ) GO TO 38
      DO 30 N = 1, NSUB
   10    READ (LU1,1000,END=900) CARD
         IF ( CARD(1) .NE. SUBC1 ) GO TO 10
         IF ( CARD(2) .NE. SUBC2 ) GO TO 10
         WRITE (LU2) CARD
            NX = 6
      DO 20 ND = 1, NDISPN
         IF ( IPSW .GT. 3 ) PRINT 9007
 9007 FORMAT('0<<< CALL SUBROUTINE INPUT FROM SUBROUTINE MAIND >>>')
      CALL INPUT ( NX )
         IF ( IPSW .GT. 3 ) PRINT 9008
 9008 FORMAT('0<<< RETURN TO SUBROUTINE MAIND FROM SUBROUTINE INPUT >>')
         IF ( KODE .NE. 0 ) GO TO 910
         WRITE (LU2) ID, ( X(I), I = 1, NX )
   20 CONTINUE
   30 CONTINUE
C     PROCESS DISPLACEMENT PRINTER PLOTS
   38    IF ( IPSW .GT. 3 ) PRINT 9004
 9004 FORMAT('0<<< CALL SUBROUTINE SEARCH FROM SUBROUTINE MAIND >>>')
      CALL SEARCH
         IF ( IPSW .GT. 3 ) PRINT 9006
 9006 FORMAT('0<<< RETURN TO SUBROUTINE MAIND FROM SUBROUTINE SEARCH >')
```

```
      IF ( KODE .NE. O ) RETURN
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     READ & TRANSLATE STRESS FILES
   39 CONTINUE
         IF ( IPSW .GT. 3 ) PRINT 90003, NFS, ICNTSF
90003 FORMAT ('O< < < READ AND TRANSLATE STRESS FILES > > >',/,
     +        'O< < <      NFS =',I2,5X,'ICNTSF =',I2)
            NROWS = O
         IF ( NFS .EQ. O ) GO TO 130
         IF ( ICNTSF .EQ. 1 ) GO TO 95
         PRINT 1004
      DO 48 I = 1, 18
            NUMBR(I) = O
   48 CONTINUE
            MORE = O
            LSKIP = 1
   40    IF ( LSKIP .LT. 6 ) GO TO 42
         PRINT 1004
            LSKIP = 1
   42    READ (LU1,1000,END=95) CARD
         IF ( CARD(3) .NE. BLANK ) PRINT 10000, CARD
         IF ( CARD(3) .EQ. STRE ) OK = 1
         IF ( CARD(1) .NE. SUBC1 ) GO TO 42
         IF ( CARD(2) .EQ. SUBC2 .AND. OK .EQ. 1 ) GO TO 45
         GO TO 42
   45 BACKSPACE LU1
         READ (LU1,1020) NOSUB
         READ (LU1,1030) ITYPE
         PRINT 10010, NOSUB, ITYPE
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     PRINT ELEMENT NAME BASED UPON NASTRAN ELEMENT TYPE NUMBER
         IF ( ITYPE .EQ.  1 ) PRINT 7001
         IF ( ITYPE .EQ.  3 ) PRINT 7003
         IF ( ITYPE .EQ.  4 ) PRINT 7004
         IF ( ITYPE .EQ.  5 ) PRINT 7005
         IF ( ITYPE .EQ.  6 ) PRINT 7006
         IF ( ITYPE .EQ.  7 ) PRINT 7007
         IF ( ITYPE  EQ.  8 ) PRINT 7008
         IF ( ITYPE .EQ.  9 ) PRINT 7009
         IF ( ITYPE .EQ. 10 ) PRINT 7010
         IF ( ITYPE .EQ. 12 ) PRINT 7012
         IF ( ITYPE .EQ. 15 ) PRINT 7015
         IF ( ITYPE .EQ. 16 ) PRINT 7016
         IF ( ITYPE .EQ. 17 ) PRINT 7017
         IF ( ITYPE .EQ. 18 ) PRINT 7018
         IF ( ITYPE .EQ. 19 ) PRINT 7019
         IF ( ITYPE .EQ. 34 ) PRINT 7034
         IF ( ITYPE .EQ. 62 ) PRINT 7062
         IF ( ITYPE .EQ 63 ) PRINT 7063
 7001 FORMAT ( 1H+, 41X, '( CROD )' )
 7003 FORMAT ( 1H+, 41X, '( CTUBE )' )
 7004 FORMAT ( 1H+, 41X, '( CSHEAR )' )
 7005 FORMAT ( 1H+, 41X, '( CTWIST )' )
 7006 FORMAT ( 1H+, 41X, '( CTRIA1 )' )
 7007 FORMAT ( 1H+, 41X, '( CTRBSC )' )
 7008 FORMAT ( 1H+, 41X, '( CTRPLT )' )
 7009 FORMAT ( 1H+, 41X, '( CTRMEM )' )
 7010 FORMAT ( 1H+, 41X, '( CONROD )' )
 7012 FORMAT ( 1H+, 41X, '( CELAS2 )' )
 7015 FORMAT ( 1H+, 41X, '( CQDPLT )' )
 7016 FORMAT ( 1H+, 41X, '( CQDMEM )' )
 7017 FORMAT ( 1H+, 41X, '( CTRIA2 )' )
 7018 FORMAT ( 1H+, 41X, '( CQUAD2 )' )
 7019 FORMAT ( 1H+, 41X, '( CQUAD1 )' )
 7034 FORMAT ( 1H+, 41X, '( CBAR )' )
 7062 FORMAT ( 1H+, 41X, '( CQDMEM1 )' )
 7063 FORMAT ( 1H+, 41X, '( CQDMEM2 )' )
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
         IF ( ITYPE .NE. 12 .AND. ITYPE .NE. 34 ) GO TO 47
         PRINT 2011
   46    READ ( LU1,1000,END=95 )  CARD
         IF ( CARD(1) .NE. TITL ) GO TO 46
      BACKSPACE LU1
            LSKIP = LSKIP + 1
      GO TO 40
   47       OK = O
            NTYPE = O
      DO 50 NTYPE = 1, 16
         IF ( ITYPE .EQ. LTYPE(NTYPE) ) GO TO 60
   50 CONTINUE
         GO TO 920
   60       LUI = LU(NTYPE)
         WRITE (LUI) NOSUB, ITYPE
            NUMBER = O
            NX = NUM(NTYPE)
         IF ( IPSW .GT. 2 ) PRINT 9003, NOSUB,ITYPE
   70    IF ( IPSW .GT. 3 ) PRINT 9012
 9012 FORMAT('O<<< CALL SUBROUTINE INPUT FROM SUBROUTINE MAIND >>>')
      CALL INPUT ( NX )
         IF ( IPSW .GT. 3 ) PRINT 9008
            NUMBER = NUMBER + 1
C        WRITE ELEMENT STRESSES INTO INDIVIDUAL SCRATCH FILES
         WRITE (LUI) ID, ( X(I), I = 1, NX )
         READ (LU1,1000,END=80) FIELD
90004 FORMAT ('O< < <      FIELD = ',20A4)
         IF ( FIELD(1) .EQ. TITL ) GO TO 90
      BACKSPACE LU1
         GO TO 70
C     THE USE OF BACKSPACE FOR EVERY LINE OF DATA IS VERY INEFFICIENT.
C     PUTTING THE DECISION STEP FOR FIELD(1) = TITL INTO SUBROUTINE
C     INPUT WOULD ELIMINATE THE NEED FOR ALL OF THESE BACKSPACES.
   80       MORE = 1
   90       NUMBR(NTYPE) = NUMBER
         PRINT 10020, NUMBER
            LSKIP = LSKIP + 1
         IF ( MORE .EQ. O ) GO TO 40
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     ALL FILES READ - BEGIN PROCESSING
   95 DO 100 N = 1, 18
            LUI = LU(N)
         IF ( NUMBR(N) .EQ. O ) GO TO  100
C     REWIND INDIVIDUAL ELEMENT STRESS SCRATCH FILES
         REWIND LUI
         IF ( IPSW .GT. 3 ) PRINT 9013
 9013 FORMAT ('O<<< CALL SPECIFIC ELEMENT SUBROUTINE FROM SUBROUTINE',
     +        ' MAIND >>>' )
         IF (LTYPE(N).EQ. 1 .OR. LTYPE(N).EQ. 3) CALL RODS   (N,NROWS)
         IF (LTYPE(N).EQ.10)                     CALL RODS   (N,NROWS)
         IF (LTYPE(N).EQ.16 .OR. LTYPE(N).EQ.62) CALL MEMBRN (N,NROWS)
         IF (LTYPE(N).EQ.63 .OR. LTYPE(N).EQ. 9) CALL MEMBRN (N,NROWS)
         IF (LTYPE(N).EQ. 4 .OR. LTYPE(N).EQ. 5) CALL PANELS (N,NROWS)
         IF (LTYPE(N).EQ.15 .OR. LTYPE(N).EQ.19) CALL PLATES (N,NROWS)
         IF (LTYPE(N).EQ.18 .OR. LTYPE(N).EQ. 7) CALL PLATES (N,NROWS)
         IF (LTYPE(N).EQ. 6 .OR. LTYPE(N).EQ.17) CALL PLATES (N,NROWS)
         IF (LTYPE(N).EQ. 8)                     CALL PLATES (N,NROWS)
         IF ( IPSW .GT. 3 ) PRINT 9014
 9014 FORMAT ('O<<< RETURN TO SUBROUTINE MAIND FROM SPECIFIC',
     +        ' ELEMENT SUBROUTINE >>>' )
  100 CONTINUE
         IF ( NROWS .EQ. O ) GO TO 105
         IF ( IPSW .GT. 3 ) PRINT 9015
 9015 FORMAT ('O<<< CALL SUBROUTINE GROUP FROM SUBROUTINE MAIND >>>')
      CALL GROUP ( NROWS )
         IF ( IPSW .GT. 3 ) PRINT 9016
 9016 FORMAT ('O<<< RETURN TO SUBROUTINE MAIND FROM SUBROUTINE GROUP >')
  105 CONTINUE
         IF ( IPSW .GT. 3 ) PRINT 9019
 9019 FORMAT ('O<<< CALL SUBROUTINE CASEDK FROM SUBROUTINE MAIND >>>')
      CALL CASEDK ( NROWS )
         IF ( IPSW .GT. 3 ) PRINT 9020
 9020 FORMAT ('O<<< RETURN TO SUBROUTINE MAIND FROM SUBROUTINE CASEDK')
 9017 FORMAT ('O< < < LUB1 =',I3,5X,'LUB2 =',I3,5X,'RETAIN',I3)
 9018 FORMAT ('O< < < LUC1 =',I3,5X,'LUC2 =',I3,5X,'RETAIN',I3)
         IF ( LUB1 .EQ. IBULK ) GO TO 500
         REWIND LUB1
         REWIND LUB2
  490    READ (LUB1,1000,END=500) CARD
         WRITE (LUB2,1000) CARD
      GO TO 490
  500 CONTINUE
      GO TO 130
  900    PRINT 8000
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      GO TO 130
  910     PRINT 8010
      GO TO 130
  920     PRINT 8020
      GO TO 130
  130 RETURN
 1000 FORMAT ( 20A4 )
 9003 FORMAT(1H1,'< < <  ELEMENT STRESS INPUT:   SUBCASE NO.',I10,
     + 5X,'ELEMENT TYPE',I5, '  > > >')
 1004 FORMAT(1H1, /////////////)
 1005 FORMAT ( 2A4 )
 9005 FORMAT(1H1, '< < <  GRID DISPLACEMENT INPUT  > > >' )
 1010 FORMAT ( I10, 8X, 3 ( 5X, E13.0 ), ( / 18X, 3 ( 5X, E13.0 ) ) )
 1020 FORMAT ( 15X, I10 )
 1030 FORMAT ( 17X, I10 )
 2000 FORMAT ( I5 )
 2010 FORMAT ( A8, 2X, I5 )
 2060 FORMAT ( 8A1 )
 8000 FORMAT ( '-***ERROR***  END OF INPUT FILE' )
 8010 FORMAT ( '-***ERROR***  INPUT FILE ENDED IN MIDDLE OF DISPLACEMENT
     + PROCESSING' )
 8020 FORMAT (1H0,'0* * *  E R R O R  * * *','/,' ELEMENT ID NUMBER',
     +        'INDICATES AN ELEMENT TYPE NOT ACCEPTED BY THIS PROGRAM')
10010 FORMAT ( '0SUBCASE NO. ', I5, '      ELEMENT TYPE ', I5 )
 2011 FORMAT('0 *** ELEMENT IS EITHER A CELAS2 OR A CBAR',
     +' ----- STRESSES NOT CHECKED ***',//)
10020 FORMAT ( '0ELEMENTS PROCESSED: ', I8 ,//)
10000 FORMAT ( 5X, 20A4 )
      END
C
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C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE RODS ( NTYPE, NROWS )
C     SEARCH ROD TYPE ELEMENTS FOR OVER-STRESSING
C     NAME(TYPE):  CROD(1), CTUBE(3), CONROD(10)
      COMMON / CTLDTA / LTYPE(18), NUM(18)
      COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
      COMMON / TEMPRT / IPSW
      COMMON / GRIDPT / KODE, ID(8)
      COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      DATA CON,ROD,CROD,BLANK/4HCONR,4HOD  ,4HCROD,4H    /
      DATA CTUB, TUBE / 4HCTUB , 4HE   /
          PRINT 1000
          IF ( IPSW .GT. 0 ) PRINT 9002
 9002 FORMAT ('0<<<<< ENTRY SUBROUTINE RODS >>>>>' )
                LUI = LU(NTYPE)
                NX = NUM(NTYPE)
                NR = NUMBR(NTYPE)
                MM = 2
               IIFLAG = 1
                NFLAG = 100
                NCHK  = 0
          IF ( LTYPE(NTYPE) .EQ. 1 ) GO TO 2
          IF ( LTYPE(NTYPE) .EQ. 3 ) GO TO 3
          PRINT 2003
                ELTYPE(1) = CON
                ELTYPE(2) = ROD
      GO TO 4
    2 CONTINUE
          PRINT 2002
                ELTYPE(1) = CROD
                ELTYPE(2) = BLANK
      GO TO 4
    3 CONTINUE
          PRINT 2004
                ELTYPE(1) = CTUB
                ELTYPE(2) = TUBE
    4 CONTINUE
          PRINT 2001
          REWIND LUI
      DO 30 N = 1, NSUB
          IF ( IFLAG .EQ. 1 ) GO TO 9
          IF ( IIFLAG .EQ. 1 ) GO TO 9
      GO TO 31
    9     READ (LUI)
          PRINT 1004, N
                IIFLAG = 0
      DO 30 M = 1, NR
          READ (LUI) ID, ( X(I), I = 1, NX )
C     TO INCLUDE POTENTIAL FAILURES, CHANGE "29" TO "10" IN NEXT LINE
          IF ( X(2) .GE. 0.0  .AND.  X(4) .GE. 0.0 ) GO TO 29
          IF ( X(1) .EQ. 0.0  .AND.  X(3) .EQ. 0.0 ) GO TO 29
          IF ( X(4) .LT. X(2) ) GO TO 50
          IF ( X(1) .EQ. 0.0 )  GO TO 40
                IF = 1
                ESTR = X(1)
                EMOS = X(2)
      GO TO 20
   40     IF ( X(4) .GE. 0.0 ) GO TO 29
                IF = 2
                ESTR = X(3)
                EMOS = X(4)
      GO TO 20
   50     IF ( X(3) .EQ. 0.0 ) GO TO 60
                IF = 2
                ESTR = X(3)
                EMOS = X(4)
      GO TO 20
   60     IF ( X(2) .GE. 0.0 ) GO TO 29
                IF = 1
                ESTR = X(1)
                EMOS = X(2)
      GO TO 20
   10           IF = 0
          IF ( X(2) .GT. 1.0  .AND.  X(4) .GT. 1.0 ) GO TO 29
          IF ( X(4) .LT. X(2) ) GO TO 70
                ESTR = X(1)
                EMOS = X(2)
      GO TO 20
   70           ESTR = X(3)
                EMOS = X(4)
   20 CONTINUE
          PRINT 2010, ELTYPE, ID, ESTR, EMOS
          IF ( IF .EQ. 0 ) PRINT 2040
          IF ( IF .EQ. 0 ) GO TO 24
          IF ( IF .EQ. 1 ) PRINT 2030
          IF ( IF .EQ. 2 ) PRINT 2020
          IF ( IPSW .GT. 3 ) PRINT 9003
      CALL GROPTS ( MM )
          IF ( IPSW .GT. 3 ) PRINT 9004
          WRITE (LUF1,2050) ELTYPE,ID,GP,NCHK,NFLAG,X(2)
                NROWS = NROWS + 1
   24 CONTINUE
               IIFLAG = 1
   29     IF ( IPSW .GT. 2 ) PRINT 9001, ID, X(2)
   30 CONTINUE
          PRINT 1001, NSUB
      RETURN
   31          INSUB = N - 1
          PRINT 1001, INSUB
      RETURN
 1000 FORMAT ( 1H1, ///////////// )
 1001 FORMAT('0    ***** STRESSES CHECKED IN THE FIRST ',I5,
     +'  SUBCASES  *****')
 1004 FORMAT(///,' SUBCASE = ',I5, / )
 2001 FORMAT(1H0,4X,'FAILURE CRITERIA:  MARGIN OF SAFETY  <=  ZERO')
 2002 FORMAT('0* * * C R O D   S T R E S S E S * * *',///)
 2003 FORMAT('0* * * C O N R O D   S T R E S S E S * * *',///)
 2004 FORMAT ('0* * * C T U B E   S T R E S S E S * * *',///)
 2010 FORMAT( 5X, 2A4, 8A1 ,'   AXIAL STRESS:  ',1PE10.3,
     +'    MARGIN OF SAFETY:  ',1PE8.1)
 2020 FORMAT ( 1H+, 80X, '***TORSION FAILURE***' )
 2030 FORMAT ( 1H+, 80X, '*** AXIAL FAILURE ***' )
 2040 FORMAT ( 1H+, 80X, '  POTENTIAL FAILURE  ' )
 2050 FORMAT ( 2A4,8A1,8A4, 2I4, 1PE18.6 )
 9001 FORMAT(1H ,'< < <  ELEMENT',2X,8A1, 5X,'VALUE CHECKED',5X,E10.4 )
 9003 FORMAT ('0< < < CALL SUBROUTINE GROPTS FROM SUBROUTINE RODS >')
 9004 FORMAT ('0< < < RETURN TO SUBROUTINE RODS FROM SUBROUTINE GROPTS')
      END
C
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C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE MEMBRN ( NTYPE, NROWS )
C     SEARCH MEMBRANE TYPE ELEMENTS FOR OVER-STRESSING
C     NAME(TYPE)   CQDMEM(16), CQDMEM1(62), CQDMEM2(63), CTRMEM(9)
      COMMON / BULKDK / CARD1,CARD2,CARD3,CARD4,PIDF,PIDD,PID1,PID2,PID3
      COMMON / CTLDTA / LTYPE(18), NUM(18)
      COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
      COMMON / TEMPRT / IPSW
      COMMON / GRIDPT / NODE, ID(8)
      COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      DATA COD,XMEM,XMEM1,XMEM2,CTR/4HCQDM,4HEM  ,4HEM1 ,4HEM2 ,4HCTRM/
      DIMENSION XLINE(2), LINE(8), YLINE(16), FAIL(3)
      PRINT 1005
          IF ( IPSW  GT  O ) PRINT 9002
 9002 FORMAT('O<<<<< ENTRY SUBROUTINE MEMBRN >>>>>')
               IIFLAG = 1
               NFLAG = 100
               NCHK  = 0
               LUI = LU(NTYPE)
               NX = NUM(NTYPE)
               NM = NUMBR(NTYPE)
          REWIND LUI
          REWIND LUB1
          REWIND LUB2
      DO 1 I = 1, 3
    1          FAIL(I) = 100.0
          IF ( LTYPE(NTYPE) .EQ. 9 ) GO TO 2
               ALPHA = COD
               ELTYPE(1) = COD
          IF ( LTYPE(NTYPE) .EQ. 63 ) GO TO 16
          IF ( LTYPE(NTYPE) .EQ. 62 ) GO TO 14
          PRINT 1003
               ELTYPE(2) = XMEM
      GO TO 18
   14     PRINT 1007
               ELTYPE(2) = XMEM1
      GO TO 18
   16     PRINT 1008
               ELTYPE(2) = XMEM2
   18 GO TO 4
    2     PRINT 1002
               ALPHA = CTR
               ELTYPE(1) = CTR
               ELTYPE(2) = XMEM
    4     PRINT 1000
          PRINT 1010
          PRINT 1001, STRMEM
      DO 80 N = 1,NSUB
          IF ( IFLAG .EQ. 1 )   GO TO 20
          IF (IIFLAG .EQ. 1 ) GO TO 20
      GO TO 99
   20          IIFLAG = 0
          READ(LUI)
          PRINT 1004,N
      DO 80 M = 1,NM
          READ(LUI) ID, ( X(I), I=1,NX )
               ICOL = 0
  100     READ (LUB1,1006) XLINE,LINE,YLINE
          IF ( IPSW .GT. 4 ) PRINT 9006, XLINE(1), ALPHA
          IF ( XLINE(1) - ALPHA ) 999, 200, 150
  150     WRITE (LUB2,1006) XLINE,LINE,YLINE
      GO TO 100
  200 CONTINUE
          IF ( IPSW .GT. 4 ) PRINT 9007, LINE, ID
      DO 250 J = 1, 8
          IF ( LINE(J) .NE. ID(J) ) GO TO 150
  250 CONTINUE
C     ---------------------------------------------------------------------
C     DETERMINE THE CURRENT PROPERTY ID OF THE ELEMENT
  300     IF ( YLINE(1) .EQ. PID1 ) ICOL = 2
          IF ( YLINE(1) .EQ. PID2 ) ICOL = 3
          IF ( YLINE(1) .EQ. PID3 ) ICOL = 4
          IF ( ICOL  EQ  O ) ICOL = 1
      DO 400 IROW = 1, 3
               IP4 = IROW + 4
               XSTR = ABS( X(IP4) )
          IF ( X(IP4) .NE. 0.0 )
     *         FAIL(IROW) = STRMEM(IROW,ICOL) / XSTR  - 1.0
          IF ( IPSW .GT. 4 ) PRINT 9008, STRMEM(IROW,ICOL), XSTR,
     *                                  IROW, FAIL(IROW), ICOL
C     ---------------------------------------------------------------------
C     DETERMINE THE CRITICAL STRESS AND MARGIN OF SAFETY
  400 CONTINUE
               EMOS = FAIL(1)
          IF ( FAIL(2) .LT. EMOS ) EMOS = FAIL(2)
          IF ( FAIL(3) .LT. EMOS ) EMOS = FAIL(3)
          IF ( IPSW .GT. 4 ) PRINT 9009, EMOS
          IF ( EMOS .GT. 0.0 ) GO TO 700
               IIFLAG = 1
          IF ( ICOL .EQ. 1  .OR.  ICOL .EQ. 2 ) GO TO 600
C     ---------------------------------------------------------------------
C     RECORD PREVIOUSLY BUCKLED PANELS WHICH ARE NOW OVER-STRESSED
          WRITE (LUB2,1006) XLINE,LINE,YLINE
          WRITE (LUF1,2050) XLINE,LINE,(YLINE(J),J=3,10),NCHK,NFLAG,EMOS
               NROWS = NROWS + 1
          PRINT 2010, ELTYPE, ID
      DO 500 ICOL = 3, 4
          IF ( EMOS .EQ. FAIL(1) ) PRINT 3000, X(5), EMOS
          IF ( EMOS .EQ. FAIL(2) ) PRINT 4000, X(6), EMOS
          IF ( EMOS .EQ. FAIL(3) ) PRINT 5000, X(7), EMOS
  500 CONTINUE
      GO TO 80
C     ---------------------------------------------------------------------
C     CHANGE THE PROPERTY ID OF PANELS WHICH JUST NOW BUCKLED
  600 CONTINUE
          IF ( YLINE(1) .EQ. PIDF ) WRITE (LUB2,1006) XLINE,LINE,YLINE
          IF ( YLINE(1) .EQ. PIDF ) GO TO 80
          IF ( ICOL .EQ. 1 ) YLINE(2) = YLINE(1)
          IF ( ICOL .EQ. 1 ) YLINE(1) = PID2
          IF ( ICOL .EQ. 2 ) YLINE(1) = PID3
          WRITE (LUB2,1006) XLINE,LINE,YLINE
          PRINT 8060, XLINE, LINE, EMOS
      GO TO 80
  700 CONTINUE
          WRITE (LUB2,1006) XLINE,LINE,YLINE
C     TO INCLUDE POTENTIAL FAILURES, CHANGE "O.O" TO "1.O" IN NEXT LINE
          IF ( EMOS .GE. 0.0 ) GO TO 80
          PRINT 2010, XLINE, LINE
      DO 750 ICOL = 1, 2
          IF ( EMOS .EQ. FAIL(1) ) PRINT 8070, X(5), EMOS
          IF ( EMOS .EQ. FAIL(2) ) PRINT 8070, X(6), EMOS
          IF ( EMOS .EQ. FAIL(3) ) PRINT 8070, X(7), EMOS
  750 CONTINUE
      GO TO 80
   80 CONTINUE
  999     READ (LUB1,1006,END=998) XLINE,LINE,YLINE
          WRITE (LUB2,1006) XLINE,LINE,YLINE
      GO TO 999
C     ---------------------------------------------------------------------
C     COPY THE REMAINDER OF THE BULK DATA DECK
  998     REWIND LUB1
          REWIND LUB2
               IHOLD = LUB1
               LUB1  = LUB2
               LUB2  = IHOLD
      PRINT 2000, NSUB
      RETURN
   99          INSUB = N - 1
      PRINT 2000, INSUB
      GO TO 999
 1000 FORMAT ( '+* * *', 16X, 'S T R E S S E S  * * *', /// )
 1001 FORMAT (//,5X,'LIMITING STRESSES:',16X,'TENSION    COMPRESSION',
     +5X,'SHEAR',/,8X,'UNBUCKLED AWAY FROM DAMAGE:',3(2PE13.3),/,8X,
     +'UNBUCKLED BORDERING DAMAGE:',3(2PE13.3),/,10X,'BUCKLED AWAY ',
     +'FROM DAMAGE:',3(2PE13.3),/,10X,'BUCKLED BORDERING DAMAGE:',
     +3(2PE13.3),/,5X,'(A VALUE OF ZERO INDICATES NO LIMITING STRESS)' )
 1002 FORMAT (7X,'C T R M E M')
 1003 FORMAT (7X,'C Q D M E M')
 1007 FORMAT (7X,'C Q D M E M 1')
 1008 FORMAT (7X,'C Q D M E M 2')
 1004 FORMAT(///,' SUBCASE:  ',I5, / )
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 1006 FORMAT ( 1H1, ///////////// )
 1007 FORMAT ( 2A4, 8A1, 16A4 )
 1010 FORMAT (5X,'FAILURE CRITERIA:  MARGIN OF SAFETY  <=  ZERO')
 2000 FORMAT('0     *****  STRESSES CHECKED IN THE FIRST ',I5,
     *'  SUBCASES  *****')
 2010 FORMAT (3X,2A4,8A1,'CRITICAL STRESS:',15X,'MARGIN OF SAFETY:')
 2050 FORMAT ( 2A4,8A1,8A4,2I4,1PE18.6 )
 3000 FORMAT(1H+,37X,1PE10.3,23X,1PE8.1,3X,'**** FAILS IN TENSION ****')
 4000 FORMAT(1H+,37X,1PE10.3,23X,1PE8.1,3X,'***FAILS IN COMPRESSION***')
 5000 FORMAT(1H+,37X,1PE10.3,23X,1PE8.1,3X,'***** FAILS IN SHEAR *****')
 6000 FORMAT('+     ***  CODMEM:')
 7000 FORMAT('+     ***  CTRMEM:')
 8000 FORMAT(1H0,18X,'ELEMENT STRESS IS  ',E15.7,'  LARGEST LIMITING',
     *' STRESS EXCEEDED IS  ',E10.4)
 8050 FORMAT (/,10X,'LIMITING STRESSES NOT EXCEEDED:', /,15X,8(1PE10.4))
 8060 FORMAT (3X, 2A4, 8A1, 31X, 'MARGIN OF SAFETY:', 1PE12.1, 8X,
     *       'ELEMENT BUCKLES')
 8070 FORMAT (1H+,37X,1PE10.3,23X,1PE8.1,7X,'POTENTIAL FAILURE')
 9001 FORMAT(1H ,'0< < <  ELEMENT',2X,8A1, 5X,'VALUE CHECKED',5X,E10.4)
 9003 FORMAT ('0< < < CALL SUBROUTINE GRDPTS FROM SUBROUTINE MEMBRN >')
 9004 FORMAT ('0< < < RETURN TO SUBROUTINE MEMBRN FROM',
     *       ' SUBROUTINE GRDPTS > > >')
 9006 FORMAT ('0< < < COMPARE BULK DATA ',1A4,4X,'TO ',1A4,4X,
     *       'FAILED ELEMENT TYPE > > >' )
 9007 FORMAT ('0< < < COMPARE BULK DATA ',8A1,'TO ',8A1,
     *       'FAILED ELEMENT ID NUMBER > > >' )
 9008 FORMAT ('0< < < COMPARE LIMITING STRESS:',1PE14.5,'  TO STRESS:',
     *      1PE14.5,/,7X,'FAIL(',I1,') =',1PE10.2,5X,'USING COLUMN',I2)
 9009 FORMAT ('0< < < CRITICAL MARGIN OF SAFETY =',1PE11.2 )
      END
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C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE PANELS ( NTYPE, NROWS )
C     SEARCH PANEL TYPE ELEMENTS FOR OVER-STRESSING
C     NAME(TYPE)   CSHEAR(4), CTWIST(5)
      COMMON / BULKDK / CARD1,CARD2,CARD3,CARD4,PIDF,PID0,PID1,PID2,PID3
      COMMON / CTLDTA / LTYPE(18), NUM(18)
      COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
      COMMON / TEMPRT / IPSW
      COMMON / GRIDPT / NODE, ID(8)
      COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      DATA CSH,EAR,CTWI,TWIST /4HCSHE,4HAR  ,4HCTWI,4HST   /
      DIMENSION XLINE(2), LINE(8), YLINE(16)
      PRINT 1000
          IF ( IPSW .GT. 0 ) PRINT 9002
 9002 FORMAT ('0<<<<< ENTRY SUBROUTINE PANELS >>>>>' )
              LUI = LU(NTYPE)
              NX = NUM(NTYPE)
              NS = NUMBR(NTYPE)
          IF ( LTYPE(NTYPE) .EQ. 4 ) GO TO 6
          PRINT 2002
              ELTYPE(1) = CTWI
              ELTYPE(2) = TWIST
      GO TO 7
    6     PRINT 2000
              ELTYPE(1) = CSH
              ELTYPE(2) = EAR
    7     PRINT 2001
          REWIND LUI
          REWIND LUB1
          REWIND LUB2
              IIFLAG = 1
              NFLAG = 100
              NCHK  = 0
      DO 30 N = 1, NSUB
          IF ( IFLAG .EQ. 1 ) GO TO 9
          IF (  IIFLAG .EQ. 1 ) GO TO 9
      GO TO 31
    9     READ(LUI)
          PRINT 1004, N
              IIFLAG = 0
      DO 30 M = 1, NS
          READ (LUI) ID, ( X(I), I = 1, NX )
C     TO INCLUDE POTENTIAL FAILURES, CHANGE "29" TO "10" IN NEXT LINE
          IF ( X(3) .GE. 0.0 ) GO TO 29
          IF ( X(1) .EQ. 0.0 ) GO TO 29
              IF = 1
          GO TO 20
   10     IF ( X(3) .GT. 1.0 ) GO TO 29
              IF = 0
   20     PRINT 2010, ELTYPE, ID, ( X(I), I = 1, NX )
          IF ( IF .EQ. 1 ) GO TO 22
          PRINT 2020
      GO TO 24
   22 CONTINUE
  200     READ (LUB1,1007) XLINE, LINE, YLINE
          IF ( IPSW .GT. 4 ) PRINT 9006, XLINE, ELTYPE
          IF ( XLINE(1) .EQ. ELTYPE(1)  .AND.  XLINE(2) .EQ. ELTYPE(2) )
     *GO TO 220
          WRITE (LUB2,1007) XLINE, LINE, YLINE
      GO TO 200
  220 CONTINUE
          IF ( IPSW .GT. 4 ) PRINT 9007, (LINE(J),J=1,8), ID
      DO 240 J = 1, 8
          IF ( LINE(J) .NE. ID(J) ) GO TO 250
  240 CONTINUE
      GO TO 260
  250 CONTINUE
          WRITE (LUB2,1007) XLINE, LINE, YLINE
          READ (LUB1,1007) XLINE, LINE, YLINE
      GO TO 220
  260 CONTINUE
          IF ( YLINE(1) .NE. PID2  .AND.  YLINE(1) .NE. PID3 )
     *GO TO 100
C     ------------------------------------------------------------------
C     RECORD PREVIOUSLY BUCKLED ELEMENTS WHICH ARE NOW OVER-STRESSED
          PRINT 2030
          WRITE (LUF1,2050) ELTYPE,ID,(YLINE(J),J=3,10),NCHK,NFLAG,X(3)
              NROWS = NROWS + 1
          WRITE (LUB2,1007) XLINE, LINE, YLINE
   24 CONTINUE
              IIFLAG = 1
   29     IF ( IPSW .GT. 2 ) PRINT 9001, ID, X(3)
      GO TO 30
C     ------------------------------------------------------------------
C     CHANGE THE PROPERTY ID OF ELEMENTS WHICH JUST NOW BUCKLED
  100 CONTINUE
          IF ( YLINE(1) .EQ. PIDF ) PRINT 2060
          IF ( YLINE(1) .EQ. PIDF )
     *    WRITE (LUB2,1007) XLINE, LINE, YLINE
          IF ( YLINE(1) .EQ. PIDF ) GO TO 30
          PRINT 2040
          IF ( YLINE(1) .EQ. PID1 ) GO TO 120
              YLINE(2) = YLINE(1)
              YLINE(1) = PID2
      GO TO 270
  120         YLINE(1) = PID3
  270     IF ( IPSW .GT. 4 ) PRINT 9008, XLINE, LINE, YLINE
          WRITE (LUB2,1007) XLINE, LINE, YLINE
   30 CONTINUE
      PRINT 1001, NSUB
      GO TO 35
   31         INSUB = N - 1
      PRINT 1001, INSUB
C     ------------------------------------------------------------------
C     COPY THE REMAINDER OF THE BULK DATA DECK
   35     READ (LUB1,1007,END=38) XLINE, LINE, YLINE
          WRITE (LUB2,1007) XLINE, LINE, YLINE
      GO TO 35
   38     REWIND LUB1
          REWIND LUB2
              IHOLD = LUB1
              LUB1  = LUB2
              LUB2  = IHOLD
      RETURN
   50     PRINT 1050, ELTYPE, ID
      RETURN
 1000 FORMAT ( 1H1, ///////////// )
 1001 FORMAT('0     *****  STRESSES CHECKED IN THE FIRST ',I5,
     *'  SUBCASES  *****')
```

```
1004 FORMAT(///,' SUBCASE:  ',I5, / )
1006 FORMAT (20A4)
1007 FORMAT (2A4,8A1,16A4)
1050 FORMAT (//,'0***** E R R O R *****',/,6X,'END OF BULK DATA DECK ',
     *        'REACHED UNEXPECTEDLY WHILE SEARCHING FOR ',2A4,8A1)
2000 FORMAT ( '0* * *  C S H E A R   S T R E S S E S   * * *', /// )
2002 FORMAT ( '0* * *  C T W I S T   S T R E S S E S   * * *', /// )
2001 FORMAT(1HO,4X,'FAILURE CRITERIA:  MARGIN OF SAFETY  <=  ZERO' )
2010 FORMAT(5X, 2A4, 8A1,'    MAX:  ',1PE10.3,'  AVG:  ',1PE10.3
     *,'    MARGIN OF SAFETY:  ',1PE8.1)
2020 FORMAT ( 1H+, 90X, 'POTENTIAL FAILURE' )
2030 FORMAT ( 1H+, 90X, '**** FAILURE ****' )
2040 FORMAT ( 1H+, 92X, 'PANEL BUCKLES' )
2050 FORMAT ( 2A4,8A1,8A4,2I4,1PE18.6 )
2060 FORMAT ( 1H+, 92X, 'ALREADY FAILED' )
9001 FORMAT(1H ,'< < <  ELEMENT',2X,8A1, 5X,'VALUE CHECKED',5X,E10.4)
9003 FORMAT ('0< < < CALL SUBROUTINE GRDPTS FROM SUBROUTINE SHEAR >')
9004 FORMAT ('0< < < RETURN TO SUBROUTINE SHEAR FROM',
     *        ' SUBROUTINE GRDPTS > > >')
9005 FORMAT ('0< < < SUBROUTINE GRDPTS ASSIGNED ',2A4,8A1,'A PID= ',
     *        2A4,'AND NODES:  ', 8A4 )
9006 FORMAT ('0< < < COMPARE BULK DATA ',2A4,'TO ',2A4,'FAILED ',
     *        'ELEMENT TYPE > > >')
9007 FORMAT ('0< < < COMPARE BULK DATA ',8A1,'TO ',8A1,'FAILED ',
     *        'ELEMENT ID NUMBER > > >')
9008 FORMAT ('0< < < ELEMENTS MATCHED:  NEW CARD:  ',2A4,8A1,18A4 )
     END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
     SUBROUTINE PLATES ( NTYPE, NROWS )
C    SEARCH PLATE TYPE ELEMENTS FOR OVER-STRESSING
C    NAME(TYPE):  CODPLT(15), CQUAD1(19), CQUAD2(18)
C    CTRBSC(7),  CTRIA1(8),  CTRIA2(17),  CTRPLT(8)
     COMMON / BULKDK / CARD1,CARD2,CARD3,CARD4,PIDF,PIDD,PID1,PID2,PID3
     COMMON / CTLDTA / LTYPE(18), NUM(18)
     COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
     COMMON / TEMPRT / IPSW
     COMMON / GRIDPT / KODE, ID(8)
     COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
     COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
     DATA CODP,CTRP,PLT,CTRB,BSC / 4HCODP,4HCTRP,4HLT  ,4HCTRB,4HSC   /
     DATA CQUA, QUAD1, QUAD2 / 4HCQUA, 4HD1  , 4HD2   /
     DATA CTRI, TRIA1, TRIA2 / 4HCTRI, 4HA1  , 4HA2   /
     DIMENSION XLINE(2), LINE(8), YLINE(10), FAIL(3), XX(3)
         PRINT 1000
            KK = 0
         IF ( IPSW .GT. 0 ) PRINT 9001
              LUI = LU( NTYPE )
               NX = NUM( NTYPE )
               NM = NUMBR(NTYPE)
               NFLAG = 100
               NCHK  = 0
               IIFLAG = 1
         REWIND LUI
         REWIND LUB1
         REWIND LUB2
     DO 10 I = 1, 3
10             FAIL(I) = 100.0
         IF ( LTYPE(NTYPE) .EQ. 18 ) GO TO 7
         IF ( LTYPE(NTYPE) .EQ. 17 ) GO TO 6
         IF ( LTYPE(NTYPE) .EQ. 19 ) GO TO 5
         IF ( LTYPE(NTYPE) .EQ. 15 ) GO TO 4
         IF ( LTYPE(NTYPE) .EQ.  6 ) GO TO 3
         IF ( LTYPE(NTYPE) .EQ.  8 ) GO TO 2
         PRINT 1001
               ELTYPE(1) = CTRB
               ELTYPE(2) = BSC
     GO TO 9
2        PRINT 1002
               ELTYPE(1) = CTRP
               ELTYPE(2) = PLT
     GO TO 9
3        PRINT 1003
               ELTYPE(1) = CTRI
               ELTYPE(2) = TRIA1
     GO TO 9
4        PRINT 1004
               ELTYPE(1) = CODP
               ELTYPE(2) = PLT
     GO TO 9
5        PRINT 1005
               ELTYPE(1) = CQUA
               ELTYPE(2) = QUAD1
     GO TO 9
6        PRINT 1006
               ELTYPE(1) = CTRI
               ELTYPE(2) = TRIA2
     GO TO 9
7        PRINT 1007
               ELTYPE(1) = CQUA
               ELTYPE(2) = QUAD2
9        PRINT 1010
         PRINT 1020, STRPLT
     DO 80 N = 1,NSUB
         IF ( IFLAG .EQ. 1 )   GO TO 20
         IF (IIFLAG .EQ. 1 ) GO TO 20
     GO TO 99
20             IIFLAG = 0
         READ(LUI)
     PRINT 1030,N
     DO 80 M = 1,NM
         READ(LUI) ID, ( X(I), I=1,NX )
               ICOL = 0
100      READ (LUB1,7010) XLINE,LINE,YLINE
         IF ( IPSW .GT. 4 ) PRINT 9004, XLINE(1), ELTYPE(1)
         IF ( XLINE(1) - ELTYPE(1) ) 999, 200, 150
150      WRITE (LUB2,7010) XLINE,LINE,YLINE
     GO TO 100
200  CONTINUE
         IF ( IPSW .GT. 4 ) PRINT 9006, LINE, ID
     DO 250 J = 1, 8
         IF ( LINE(J) .NE. ID(J) ) GO TO 150
250  CONTINUE
C    ------------------------------------------------------------------
C    DETERMINE THE CURRENT PROPERTY ID OF THE ELEMENT
300      IF ( YLINE(1) .EQ. PID1 ) ICOL = 2
         IF ( YLINE(1) .EQ. PID2 ) ICOL = 3
         IF ( YLINE(1) .EQ. PID3 ) ICOL = 4
         IF ( ICOL .EQ. 0 ) ICOL = 1
C    ------------------------------------------------------------------
C    DETERMINE THE CRITICAL STRESS AND MARGIN OF SAFETY
     DO 400 IROW = 1, 3
               IP5  = IROW + 5
               IP13 = IROW + 13
               XSTR = ABS( X(IP5) )
               XX(IROW) = ABS( X(IP13) )
         IF ( XX(IROW) .GT. XSTR ) GO TO 320
               XX(IROW) = X(IP5)
     GO TO 340
320            XSTR = XX(IROW)
               XX(IROW) = X(IP13)
340      IF ( XSTR .NE. 0.0 )
     *         FAIL(IROW) = STRPLT(IROW,ICOL) / XSTR  - 1.0
         IF ( IPSW .GT. 4 ) PRINT 9008, STRPLT(IROW,ICOL), XSTR,
     *                                  IROW, FAIL(IROW), ICOL
400  CONTINUE
               ENOS = FAIL(1)
         IF ( FAIL(2) .LT. ENOS ) ENOS = FAIL(2)
         IF ( FAIL(3) .LT. ENOS ) ENOS = FAIL(3)
         IF ( IPSW .GT. 4 ) PRINT 9010, ENOS
         IF ( ENOS .GT. 0.0 ) GO TO 700
               IIFLAG = 1
         IF ( ICOL .EQ. 1  .OR.  ICOL .EQ. 2 ) GO TO 600
C    ------------------------------------------------------------------
C    RECORD PREVIOUSLY BUCKLED PANELS WHICH ARE NOW OVER-STRESSED
         WRITE (LUB2,7010) XLINE,LINE,YLINE
         WRITE (LUF1,5010) XLINE,LINE,(YLINE(J),J=3,10),NCHK,NFLAG,ENOS
               NROWS = NROWS + 1
         PRINT 1040, ELTYPE, ID
     DO 500 ICOL = 3, 4
         IF ( ENOS .EQ. FAIL(1) ) PRINT 1042, XX(1), ENOS
```

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      DIMENSION  LINE1(8),  LINE2(8)
      DATA CROD, CONR, BLANK, CTUB / 4HCROD, 4HCONR, 4H    , 4HCTUB /
          IF ( IPSW .GT. 3 ) PRINT 9001
 9001 FORMAT ('O<<<<< ENTRY SUBROUTINE GRDPTS >>>>>')
          BACKSPACE LUB1
                NTRIP = 0
                PROPID(1) = BLANK
                PROPID(2) = BLANK
   10     READ (LUB1,1000,END=170) CARD
          IF ( CARD(1) .NE. ELTYPE(1) ) GO TO 10
          IF ( CARD(2) .EQ. ELTYPE(2) ) GO TO 20
      GO TO 10
   20     BACKSPACE LUB1
          IF ( ELTYPE(1) .EQ. CROD  .OR.  ELTYPE(1) .EQ. CTUB ) GO TO 70
          IF ( ELTYPE(1) .EQ. CONR ) GO TO 140
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     ELEMENTS WITH THREE OR FOUR CORNERS
   30     READ (LUB1,2000,END=170) XLINE1, LINE1, XLINE2
      DO 40 I = 1, 8
          IF ( ID(I) .NE. LINE1(I) ) GO TO 30
   40 CONTINUE
                PROPID(1) = XLINE2(1)
                PROPID(2) = XLINE2(2)
      DO 55 I=1,8
                J = I + 2
                GP(I) = XLINE2(J)
   55 CONTINUE
          IF ( N .NE. 3 ) GO TO 60
                GP(7) = BLANK
                GP(8) = BLANK
   60 CONTINUE
          BACKSPACE LUB1
      RETURN
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CROD AND CTUBE ELEMENTS
   70     READ (LUB1,3000,END=170) XLINE1, LINE1, XLINE3, LINE2, XLINE4
      DO 80 I = 1, 8
          IF ( ID(I) .NE. LINE1(I) ) GO TO 90
   80 CONTINUE
      GO TO 110
   90 DO 100 I = 1, 8
          IF ( ID(I) .NE. LINE2(I) ) GO TO 70
  100 CONTINUE
      GO TO 120
  110           GP(1) = XLINE3(3)
                GP(2) = XLINE3(4)
                GP(3) = XLINE3(5)
                GP(4) = XLINE3(6)
      GO TO 130
  120           GP(1) = XLINE4(3)
                GP(2) = XLINE4(4)
                GP(3) = XLINE4(5)
                GP(4) = XLINE4(6)
  130           GP(5) = BLANK
                GP(6) = BLANK
                GP(7) = BLANK
                GP(8) = BLANK
          BACKSPACE LUB1
      RETURN
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CONROD ELEMENTS
  140     READ (LUB1,4000,END=170) XLINE1, LINE1, XLINE5
      DO 150 I = 1, 8
          IF ( ID(I) .NE. LINE1(I) ) GO TO 140
  150 CONTINUE
                GP(1) = XLINE5(1)
                GP(2) = XLINE5(2)
                GP(3) = XLINE5(3)
                GP(4) = XLINE5(4)
      GO TO 130
  170 CONTINUE
          IF ( NTRIP .EQ. 1 ) PRINT 5000, ELTYPE, ID
          IF ( NTRIP .EQ. 1 ) RETURN
                NTRIP = 1
          REWIND LUB1
      GO TO 10
 1000 FORMAT (20A4)
 2000 FORMAT (2A4,8A1,10A4)
 3000 FORMAT (2A4,8A1,6A4,8A1,8A4)
 4000 FORMAT (2A4,8A1,4A4)
 5000 FORMAT (1HO,'*****  P O T E N T I A L   E R R O R  *****',/,6X,
     * 'SUBROUTINE GRDPTS FOUND NO GRID POINTS FOR CARD:  ',2A4,8A1,//)
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE GROUP ( NROWS )
C     REMOVE APPROPRIATE ELEMENTS FROM NASTRAN BULK DATA DECK
      COMMON / BULKDK / CARD1,CARD2,CARD3,CARD4,PIDF,PIDD,PID1,PID2,PID3
      COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
      COMMON / MATIDS / XMIDD, XMIDF
      COMMON / TEMPRT / IPSW
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      DATA CROD, CTUB, CON, ROD / 4HCROD, 4HCTUB, 4HCONR, 4HOD   /
      DATA BLANK / 4H    /
      DIMENSION ELTYP1(2),ELNUM1(2),GP1(2,4)
      DIMENSION ELTYP2(2),ELNUM2(2),GP2(2,4), ELNUM(2)
          PRINT 2000
          IF ( IPSW .GT. 0 ) PRINT 9001
          REWIND LUF1
          REWIND LUF2
          REWIND LUB1
          REWIND LUB2
                NUMPAS = 1
                IF1 = 1
                IF2 = 2
          IF ( IPSW .GT. 5 ) PRINT 9805, LUF1, LUF2, IF1, IF2
  100 CONTINUE
                NFAIL = 0
                ISWTCH = 0
  105           JSWTCH = 0
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     GROUP FAILED ELEMENTS THAT ARE CONNECTED TO EACH OTHER
          IF ( IPSW .GT. 2 ) PRINT 9002
  110 DO 300  I = 1, NROWS
          READ (LUF1,4000,END=600) ELTYP1,ELNUM1,GP1,NCHK,NFLAG1,EMOS1
          IF ( IPSW .GT. 4 ) PRINT 9003, IF1, ELTYP1, ELNUM1,
     *                               GP1, NCHK, NFLAG1, EMOS1
          IF ( ISWTCH .EQ. 1 )  GO TO  120
          IF ( NFLAG1 .LT. NUMPAS )  GO TO 300
                ISWTCH = 1
                NFLAG1 = NUMPAS
          WRITE (LUGP,4000) ELTYP1,ELNUM1,GP1,NCHK,NFLAG1,EMOS1
          IF ( IPSW .GT. 2 ) PRINT 9007, ELTYP1, ELNUM1, GP1,
     *                               NCHK, NFLAG1, EMOS1
                NFAIL = NFAIL + 1
  120 CONTINUE
          IF ( NFLAG1 .NE. NUMPAS )  GO TO  300
          IF ( NCHK .EQ. 1 ) GO TO 300
          IF ( IPSW .GT. 3 ) PRINT 9011
      CALL ELNODE  ( ELTYP1(1),ELTYP1(2), ELNUM(1),ELNUM(2), N, KK,IPSW)
          IF ( IPSW .GT. 3 ) PRINT 9012
          REWIND LUF1
      DO 280  K = 1, NROWS
          READ (LUF1,4000,END=600) ELTYP2,ELNUM2,GP2,NCHK,NFLAG2,EMOS2
          IF ( IPSW .GT. 4 ) PRINT 9004, IF1, ELTYP2, ELNUM2,
     *                               GP2, NCHK, NFLAG2, EMOS2
          IF ( K .EQ. I )  NCHK = 1
          IF ( K .EQ. I )  GO TO 170
      GO TO 180
  170 CONTINUE
          WRITE (LUF2,4000) ELTYP1,ELNUM1,GP1,NCHK,NFLAG1,EMOS1
          IF ( IPSW .GT. 4 ) PRINT 9005, IF2, ELTYP1, ELNUM1,
     *                               GP1, NCHK, NFLAG1, EMOS1
      GO TO 280
  180 CONTINUE
          IF ( NFLAG2 .GT. NUMPAS )  GO TO 190
          WRITE (LUF2,4000) ELTYP2,ELNUM2,GP2,NCHK,NFLAG2,EMOS2
          IF ( IPSW .GT. 4 ) PRINT 9006, IF2, ELTYP2, ELNUM2,
     *                               GP2, NCHK, NFLAG2, EMOS2
      GO TO 280
  190 CONTINUE
```

```
      IF ( IPSW .GT. 3 ) PRINT 9011
   CALL ELNODE  ( ELTYP2(1),ELTYP2(2), ELNUM(1),ELNUM(2), NN,KK,IPSW)
      IF ( IPSW .GT. 3 ) PRINT 9012
   DO  280  L = 1, N
   DO 240  M = 1, NN
      IF ( GP1(1,L) .EQ. GP2(1,M)  .AND.  GP1(2,L) .EQ. GP2(2,M) )
  +GO TO  200
   GO TO 240
200 CONTINUE
           NFLAG2 = NUMPAS
           NFAIL = NFAIL + 1
           JSWTCH = 1
      WRITE (LUGP,4000) ELTYP2,ELNUM2,GP2,NCHK,NFLAG2,EMOS2
      IF ( IPSW .GT. 2 ) PRINT 9008, ELTYP2, ELNUM2, GP2,
  *                               NCHK, NFLAG2, EMOS2
      WRITE (LUF2,4000) ELTYP2,ELNUM2,GP2,NCHK,NFLAG2,EMOS2
      IF ( IPSW .GT. 4 ) PRINT 9006, IF2, ELTYP2, ELNUM2,
  *                               GP2, NCHK, NFLAG2, EMOS2
   GO TO 280
240 CONTINUE
260 CONTINUE
      WRITE (LUF2,4000) ELTYP2,ELNUM2,GP2,NCHK,NFLAG2,EMOS2
      IF ( IPSW .GT. 4 ) PRINT 9006, IF2, ELTYP2, ELNUM2,
  *                               GP2, NCHK, NFLAG2, EMOS2
280 CONTINUE
           IHOLD = LUF1
           LUF1  = LUF2
           LUF2  = IHOLD
           IHOLD = IF1
           IF1   = IF2
           IF2   = IHOLD
      IF ( IPSW .GT. 5 ) PRINT 9005, LUF1, LUF2, IF1, IF2
      REWIND LUF1
      REWIND LUF2
   DO 290  MM = 1, I
      READ (LUF1,1000,END=600) CARD
      IF ( IPSW .GT. 2 ) PRINT 9010, IF1, CARD
290 CONTINUE
300 CONTINUE
      IF ( ISWTCH .EQ. 0 )  GO TO  480
      IF ( JSWTCH .EQ. 0 ) GO TO 310
      REWIND LUF1
   GO TO 105
310 CONTINUE
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     SELECT MOST SEVERELY STRESSED OF THE GROUPED ELEMENTS
      REWIND  LUF1
      REWIND  LUF2
      REWIND  LUGP
           ELTYPE(1) = BLANK
           ELTYPE(2) = BLANK
           ELNUM(1)  = BLANK
           ELNUM(2)  = BLANK
           FAIL = 0.0
   DO 320  I = 1, NFAIL
      READ (LUGP,4000) ELTYP1,ELNUM1,GP1,NCHK,NFLAG1,EMOS1
      IF ( IPSW .GT. 4 ) PRINT 9009, ELTYP1, ELNUM1, GP1,
  *                               NCHK, NFLAG1, EMOS1
      IF ( IPSW .GT. 5 ) PRINT 9008, EMOS1, FAIL
      IF ( EMOS1 .LT. FAIL )  GO TO  340
C     EMOS IS THE "ELEMENT MARGIN OF SAFETY"
320 CONTINUE
   GO TO  360
340 CONTINUE
           ELNUM(1)  = ELNUM1(1)
           ELNUM(2)  = ELNUM1(2)
           ELTYPE(1) = ELTYP1(1)
           ELTYPE(2) = ELTYP1(2)
           FAIL = EMOS1
           JFLAG = 1
   GO TO 320
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CHANGE APPROPRIATE ELEMENT PROPERTY ID
360 CONTINUE
           ITT = 1
      READ (LUB1,1000,END=650) CARD
      IF ( IPSW .GT. 4 ) PRINT 9020, ELTYPE,ELNUM,ITT,CARD
      IF ( CARD(1) .EQ. ELTYPE(1) .AND. CARD(2) .EQ. ELTYPE(2) )
  +GO TO  380
      WRITE (LUB2,1000) CARD
   GO TO  360
380 CONTINUE
      BACKSPACE   LUB1
      IF ( ELTYPE(1) .EQ. CROD  .OR.  ELTYPE(1) .EQ. CTUB) GO TO 460
      IF ( ELTYPE(1) .EQ. CON  .AND.  ELTYPE(2) .EQ. ROD ) GO TO 525
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CHECK ELEMENTS WITH THREE OR FOUR NODES
400 CONTINUE
      READ (LUB1,1000,END=650) CARD
           ITT = 2
      IF ( IPSW .GT. 4 ) PRINT 9020, ELTYPE,ELNUM,ITT,CARD
      IF ( CARD(3) .EQ. ELNUM(1)  .AND.  CARD(4) .EQ. ELNUM(2) )
  +GO TO  420
      WRITE (LUB2,1000) CARD
   GO TO  400
420 PRINT 9901, ( CARD(L),L=1,4 ), CARD(5),CARD(6), PIDF
           CARD(5) = PIDF
           CARD(6) = BLANK
      WRITE (LUB2,1000) CARD
   GO TO  540
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CHECK CROD AND CTUBE ELEMENTS
460 CONTINUE
      READ (LUB1,1000,END=650) CARD
           ITT = 3
      IF ( IPSW .GT. 4 ) PRINT 9020, ELTYPE,ELNUM,ITT,CARD
      IF ( CARD(3) .EQ. ELNUM(1)  .AND.  CARD(4) .EQ. ELNUM(2) )
  +GO TO 500
      IF ( CARD(11) .EQ. ELNUM(1)  .AND.  CARD(12) .EQ. ELNUM(2) )
  +GO TO  520
      WRITE (LUB2,1000) CARD
   GO TO 460
500 PRINT 9901,  ( CARD(L),L=1,4 ), CARD(5),CARD(6), PIDF
           CARD(5) = PIDF
           CARD(6) = BLANK
      WRITE (LUB2,1000) CARD
   GO TO  540
520 PRINT 9901, CARD(1),CARD(2), (CARD(L),L=11,14), PIDF
           CARD(13) = PIDF
           CARD(14) = BLANK
      WRITE (LUB2,1000) CARD
           JFLAG = 2
   GO TO  540
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CHECK CONROD ELEMENTS
525 CONTINUE
      READ (LUB1,1000,END=650) CARD
      IF ( CARD(3) .EQ. ELNUM(1)  .AND.  CARD(4) .EQ. ELNUM(2) )
  +GO TO 530
      WRITE (LUB2,1000) CARD
   GO TO 525
530 CONTINUE
      PRINT 9902,  ( CARD(L), L = 1, 4 ), CARD(9), CARD(10), XMIDF
           CARD(9)  = XMIDF
           CARD(10) = BLANK
      WRITE (LUB2,1000) CARD
540 CONTINUE
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CALL SUBROUTINE GPFAIL TO ADD THE NODES OF THE FAILED ELEMENT
C          TO THE FILE OF GRID POINTS BORDERING DAMAGE
      IF ( IPSW .GT. 3 ) PRINT 9013
   CALL GPFAIL ( JFLAG )
      IF ( IPSW .GT. 3 ) PRINT 9014
550   READ (LUB1,1000,END=560) CARD
      WRITE (LUB2,1000) CARD
   GO TO 550
560 CONTINUE
      REWIND LUGP
      REWIND LUB1
      REWIND LUB2
           IHOLD = LUB1
           LUB1 = LUB2
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          LUB2 = IHOLD
          NUMPAS = NUMPAS + 1
      GO TO 100
  600     PRINT 4020
      GO TO 480
  480 CONTINUE
          IF ( IPSW .GT. 3 ) PRINT 9015
      CALL PIDDAM
          IF ( IPSW .GT. 3 ) PRINT 9016
      RETURN
  650 CONTINUE
          PRINT 4040, ELTYPE,ELNUM,NUMPAS,NFAIL,CARD
      RETURN
 1000 FORMAT ( 20A4 )
 2000 FORMAT (1H1,///////////)
 4000 FORMAT ( 12A4,2I4,E10.6 )
 4010 FORMAT (8X,2A4,24X,2A4)
 4020 FORMAT('0END OF DATA SET OF FAILED ELEMENTS REACHED UNEXPECTEDLY')
 4040 FORMAT (1H1,///,'* * * * * P O T E N T I A L   E R R O R * * * *',
     +' *',//,12X,'END OF BULK DATA FILE REACHED UNEXPECTEDLY.',/,12X,
     +'PROGRAM WAS SEARCHING FOR ',4A4,' ON PASS NUMBER',I4,' WITH',I3,
     +' GROUPED ELEMENTS.',//,12X,'THE LAST LINE READ FROM THE BULK DATA
     + DECK WAS:',/,12X,20A4,1H1)
 9001 FORMAT ('0<<<<<  ENTRY SUBROUTINE GROUP  >>>>>')
 9002 FORMAT ('0< < < ACTION    FILE   TYPE     NUMBER   ',
     *          4('GRD PT   '),' CHK  FLAG   E.N.O.S.',//)
 9003 FORMAT ('0< < < READ(I)   FAIL',I1,2X, 6(2A4,1X),2I4,1PE15.6 )
 9004 FORMAT ('0< < < READ(K)   FAIL',I1,2X, 6(2A4,1X),2I4,1PE15.6 )
 9005 FORMAT ('0< < < WRITE(I)  FAIL',I1,2X, 6(2A4,1X),2I4,1PE15.6 )
 9006 FORMAT ('0< < < WRITE(K)  FAIL',I1,2X, 6(2A4,1X),2I4,1PE15.6 )
 9007 FORMAT ('0< < < WRITE(I)  GROUP  ', 6(2A4,1X),2I4,1PE15.6 )
 9008 FORMAT ('0< < < WRITE(K)  GROUP  ', 6(2A4,1X),2I4,1PE15.6 )
 9009 FORMAT ('0< < < READ      GROUP  ', 6(2A4,1X),2I4,1PE15.6 )
 9010 FORMAT ('0< < < READ      FAIL',I1,2X, 20A4 )
 9011 FORMAT ('0< < < CALL SUBROUTINE ELNODE FROM SUBROUTINE GROUP >')
 9012 FORMAT('0< < < RETURN TO SUBROUTINE GROUP FROM SUBROUTINE ELNODE')
 9013 FORMAT ('0< < < CALL SUBROUTINE GPFAIL FROM SUBROUTINE GROUP >')
 9014 FORMAT('0< < < RETURN TO SUBROUTINE GROUP FROM SUBROUTINE GPFAIL')
 9015 FORMAT ('0< < < CALL SUBROUTINE PIDDAM FROM SUBROUTINE GROUP')
 9016 FORMAT('0< < < RETURN TO SUBROUTINE GROUP FROM SUBROUTINE PIDDAM')
 9020 FORMAT ('0< < < COMPARE FAILED ELEMENT:  ',4A4,'AT LOCATION',I3,/,
     *          12X,'TO BULK DATA CARD:  ',20A4 )
 9801 FORMAT(100X,'ISWTCH=',I3,/,100X,'JSWTCH=',I3)
 9802 FORMAT(100X,'NFLAG1=',I3,/,100X,'NUMPAS=',I3)
 9803 FORMAT(100X,'I=',I3)
 9804 FORMAT(100X,'K=',I3,3X,'I=',I3)
 9805 FORMAT(100X,'LUF1=',I3,3X,'LUF2=',I3,
     *          /,100X,'IF1 =',I3,3X,'IF2 =',I3)
 9806 FORMAT(100X,'L=',I3,3X,'N=',I3)
 9808 FORMAT(100X,'ENOS1=',1PE14.6,/,100X,'FAIL=',1PE15.6)
 9901 FORMAT (//,8X,'*****  THE FAILED ELEMENT IS ', 4A4, '*****',/,13X,
     *          'THE FORMER PROPERTY ID WAS',4X,2A4,/,13X,
     *          'THE NEW PROPERTY ID WILL BE   ',1A4,/)
 9902 FORMAT (//,8X,'*****  THE FAILED ELEMENT IS ',4A4,'*****',/,13X,
     *          'THE FORMER MATERIAL ID WAS',4X,2A4,/,13X,
     *          'THE NEW MATERIAL ID WILL BE   ',1A4,/)
      END
C
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C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE ELNODE ( PART1,PART2, GD1,GD2, N, KK, IPSW )
      DATA CSHE,CTWI,CODM,CODP,COUA/4HCSHE,4HCTWI,4HCODM,4HCODP,4HCOUA/
      DATA CTRM, CTRI, CTRB, CTRP / 4HCTRM , 4HCTRI , 4HCTRB , 4HCTRP /
      DATA CROD,CONR,CBAR,CTUB,CELA/4HCROD,4HCONR,4HCBAR,4HCTUB,4HCELA/
          IF ( IPSW .GT. 3 ) PRINT 9001, PART1,PART2,GD1,GD2
 9001 FORMAT (100X,'ENTRY ELNODE WITH:  ',4A4)
          N = 0
          IF ( PART1 .EQ. CSHE  .OR.  PART1 .EQ. CTWI ) N = 4
          IF ( PART1 .EQ. CODM  .OR.  PART1 .EQ. COUA ) N = 4
          IF ( PART1 .EQ. CODP )                         N = 4
          IF ( PART1 .EQ. CTRM  .OR.  PART1 .EQ. CTRI ) N = 3
          IF ( PART1 .EQ. CTRB  .OR.  PART1 .EQ. CTRP ) N = 3
          IF ( PART1 .EQ. CROD  .OR.  PART1 .EQ. CONR ) N = 2
          IF ( PART1 .EQ. CBAR  .OR.  PART1 .EQ. CTUB ) N = 2
          IF ( PART1 .EQ. CELA )                         N = 2
          IF ( N.EQ.0  .AND.  KK.EQ.0 ) PRINT 1000, PART1,PART2,GD1,GD2
      RETURN
 1000 FORMAT (/,'0***  POTENTIAL ERROR:  NUMBER OF ELEMENT NODES',/,
     *          24X,'NOT ASSIGNED IN SUBROUTINE ELNODE FOR:  ',4A4,/)
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE GPFAIL  ( JFLAG )
      COMMON / TEMPRT / IPSW
      COMMON / INOUT  / CARD(20), ELTYPE(2), GP(8), X(16), PROPID(2)
      COMMON / UNITS3 / LUC1, LUC2, LUD1, LUD2
      DIMENSION   TEMP(2)
          IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT ('0<<<<< ENTRY SUBROUTINE GPFAIL >>>>>')
          IF ( IPSW .GT. 4 ) PRINT 9002, CARD
 9002 FORMAT ('0< < < FAILED ELEMENT IS:  ',20A4)
          REWIND LUD1
          REWIND LUD2
              L = 1
              N = 2
          IF ( JFLAG .NE. 2 ) GO TO 100
              NN = 12
              L = 9
      GO TO 140
  100 CONTINUE
              KK = 0
          IF ( IPSW .GT. 2 ) PRINT 9003
      CALL ELNODE ( CARD(1),CARD(2), CARD(3),CARD(4), N, KK, IPSW )
          IF ( IPSW .GT. 3 ) PRINT 9004
              NN = 2 * N
  140 CONTINUE
      DO 300  I = L, NN, 2
              J = I + 8
              JP1 = J + 1
  180 CONTINUE
          READ (LUD1,2000,END=220) TEMP
          IF ( CARD(J) .EQ. TEMP(1)  .AND.  CARD(JP1) .EQ. TEMP(2) )
     +GO TO 260
      GO TO 180
  220     WRITE (LUD2,2000) CARD(J), CARD(JP1)
          IF ( IPSW .GT. 4 ) PRINT 9005, CARD(J), CARD(JP1)
  260     REWIND LUD1
  300 CONTINUE
  340     READ (LUD1,2000,END=380) TEMP
          WRITE (LUD2,2000) TEMP
          IF ( IPSW .GT. 4 ) PRINT 9005, TEMP
      GO TO 340
  380 CONTINUE
          REWIND LUD1
          REWIND LUD2
              IHOLD  = LUD1
              LUD1 = LUD2
              LUD2 = IHOLD
      RETURN
 2000 FORMAT ( 2A4 )
 9003 FORMAT ('0< < < CALL SUBROUTINE ELNODE FROM SUBROUTINE GPFAIL >')
 9004 FORMAT ('0< < < RETURN TO SUBROUTINE GPFAIL FROM',
     *          ' SUBROUTINE ELNODE > > >')
 9005 FORMAT ('0< < < GRID POINT  ',2A4,'WRITTEN INTO DAMAGE FILE')
C     LUB1 IS LOGICAL UNIT OF NASTRAN BULK DATA DECK  ( RETAINED )
C     LUB2 IS LOGICAL UNIT OF UPDATED BULK DATA DECK ( TEMP. )
C     LUF1 AND LUF2 ARE LOGICAL UNITS OF FAILED ELEMENTS DISKS ( TEMP. )
C     LUGP IS LOGICAL UNIT OF GROUPED ELEMENTS DISK ( TEMP. )
C     LUD1 IS LOGICAL UNIT OF GRID POINTS BORDERING DAMAGE ( RETAINED )
C     LUD2 IS LOGICAL UNIT OF UPDATED POINTS BORDERING DAMAGE ( TEMP. )
C     "1" VARIABLES REFER TO ROW "I"
C     "2" VARIABLES REFER TO ROW "K"
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE PIDDAM
C     CHANGE PROPERTY ID NUMBERS OF ELEMENTS BORDERING NEW DAMAGE
      COMMON / BULKDK / CARD1,CARD2,CARD3,CARD4,PIDF,PIDD,PID1,PID2,PID3
      COMMON / MATIDS / XMIDD, XMIDF
      COMMON / TEMPRT / IPSW
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      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      COMMON / UNITS3 / LUC1, LUC2, LUD1, LUD2
      DIMENSION CARD(20), LINE(23)
      DATA BLANK / 4H     /
      DATA CBAR, CONR, XOD, CELA / 4HCBAR , 4HCONR , 4HOD   ,4HCELA /
         IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT (1H1,'<<<<< ENTRY SUBROUTINE PIDDAM >>>>>' )
              KK = 1
         REWIND LUB1
         REWIND LUB2
         PRINT 2000
         PRINT 3100
C     ------------------------------------------------------------------
C     BEGIN READING THE BULK DATA DECK
  100    READ (LUB1,1000) CARD
         IF ( IPSW .GT. 4 ) PRINT 9002, CARD
 9002 FORMAT ('O< < < READ FROM BULK DATA AT 100:  ',20A4 )
  125    IF ( CARD(1) - CARD3 ) 200, 175, 175
  150    READ (LUB1,1000) CARD
         IF ( IPSW .GT. 4 ) PRINT 9003, CARD
 9003 FORMAT ('O< < < READ FROM BULK DATA AT 150:  ',20A4 )
  175         K2FLAG = 0
         IF ( IPSW .GT. 3 ) PRINT 9004
 9004 FORMAT ('O< < < CALL SUBROUTINE ELNODE FROM SUBROUTINE PIDDAM')
      CALL ELNODE ( CARD(1),CARD(2), CARD(3),CARD(4), N, KK, IPSW )
         IF ( IPSW .GT. 3 ) PRINT 9005
 9005 FORMAT ('O< < < RETURN TO SUBROUTINE PIDDAM FROM ',
     +             'SUBROUTINE ELNODE > > >' )
         IF ( IPSW .GT. 5 ) PRINT 9008, N, (CARD(I),I=1,4)
 9008 FORMAT ('O< < < SUBROUTINE ELNODE ASSIGNED',I2,' NODFS FOR ',4A4)
         IF ( N .NE. 0 ) GO TO 300
         WRITE (LUB2,1000) CARD
         IF ( IPSW .GT. 4 ) PRINT 9007, CARD
      GO TO 100
  200 CONTINUE
         WRITE (LUB2,1000) CARD
      GO TO 5000
  300 CONTINUE
         REWIND LUD1
         IF ( N .NE. 2 ) GO TO 600
C     ------------------------------------------------------------------
C     CHECK ALL ELEMENTS WITH TWO NODES
         IF ( CARD(1) .EQ. CELA ) GO TO 580
         IF ( CARD(1) .EQ. CBAR .AND. CARD(2) .EQ. BLANK ) GO TO 560
         IF ( CARD(1) .EQ. CONR .AND. CARD(2) .EQ. XOD) GO TO 560
         IF ( CARD(13) .EQ. PIDD   .OR.  CARD(13) .EQ. PIDF ) GO TO 350
      GO TO 400
  350    IF ( CARD(5) .EQ. PIDD  .OR.  CARD(5) .EQ. PIDF ) GO TO 800
  400    READ (LUD1,3000,END=800) GA, GB
         IF ( IPSW .GT. 5 ) PRINT 9006, GA, GB
 9006 FORMAT ('O< < < GRID POINT ', 2A4, ' READ FROM DAMAGE FILE')
         IF ( CARD(5) .EQ. PIDD   .OR.  CARD(5) .EQ. PIDF ) GO TO 500
         IF ( CARD(7) .EQ. GA    .AND.  CARD(8) .EQ. GB ) GO TO 450
         IF ( CARD(9) .EQ. GA    .AND.  CARD(10) .EQ. GB ) GO TO 450
      GO TO 500
  450         CARD(6) = CARD(5)
              CARD(5) = PIDD
              K2FLAG = 1
  500    IF ( CARD(13).EQ.PIDD  .OR.  CARD(13).EQ.PIDF ) GO TO 400
         IF ( CARD(15) .EQ. GA   .AND.  CARD(16) .EQ. GB ) GO TO 520
         IF ( CARD(17) .EQ. GA   .AND.  CARD(18) .EQ. GB ) GO TO 520
      GO TO 400
  520         CARD(14) = CARD(13)
              CARD(13) = PIDD
              K2FLAG = 1
      GO TO 400
  560 CONTINUE
C     PROGRAM IS NOT EQUIPPED TO CHANGE CBAR OR CELAS ELEMENTS
         IF ( CARD(9) .EQ. XMIDF  .AND.  CARD(1) .EQ. CONR ) GO TO 800
  565    READ (LUD1,3000,END=800) GA, GB
      DO 570 II = 1, N
              NN   = 2 * II + 3
              NNP1 = NN + 1
         IF ( CARD(NN) .EQ. GA   .AND.  CARD(NNP1) .EQ. GB ) GO TO 575
  570 CONTINUE
      GO TO 565
  575    IF ( CARD(9) .EQ. XMIDD  .OR.  CARD(1) .EQ. CBAR ) GO TO 800
              CARD(9)  = XMIDD
              CARD(10) = BLANK
              K2FLAG   = 1
      GO TO 800
  580 CONTINUE
         READ (LUD1,3000,END=800) GA, GB
         IF ( CARD(7) .EQ. GA  .AND.  CARD(8) .EQ. GB ) GO TO 585
         IF ( CARD(11) .EQ. GA  .AND.  CARD(12) .EQ. GB ) GO TO 585
      GO TO 580
  585         K2FLAG = 1
      GO TO 800
  600 CONTINUE
C     ------------------------------------------------------------------
C     CHECK ALL ELEMENTS WITH THREE OR FOUR NODES
         IF ( CARD(5) .EQ. PIDF ) GO TO 800
  620    READ (LUD1,3000,END=800) GA, GB
         IF ( IPSW .GT. 5 ) PRINT 9006, GA, GB
      DO 700  II = 1, N
              NN = 2 * II + 5
              NNP1 = NN + 1
         IF ( CARD(NN) .EQ. GA  .AND.  CARD(NNP1) .EQ. GB ) GO TO 720
  700 CONTINUE
      GO TO 620
  720    IF ( CARD(5) .EQ. PID1  .OR.  CARD(5) .EQ. PID3 ) GO TO 800
         IF ( CARD(5) .EQ. PID2 ) CARD(5) = PID3
              K2FLAG = 1
         IF ( CARD(5) .EQ. PID3 ) GO TO 800
              CARD(6) = CARD(5)
              CARD(5) = PID1
      GO TO 800
  800 CONTINUE
         IF ( K2FLAG .EQ. 1 ) PRINT 3200, CARD
         WRITE (LUB2,1000) CARD
         IF ( IPSW .GT. 4 ) PRINT 9007, CARD
 9007 FORMAT ('O< < < WRITE TO  BULK DATA FILE:   ', 20A4 )
      GO TO 150
 5000 CONTINUE
C     ------------------------------------------------------------------
C     COPY REMAINDER OF THE BULK DATA DECK
         READ (LUB1,1000,END=5100) CARD
         IF ( IPSW .GT. 5 ) PRINT 9007, CARD
         WRITE (LUB2,1000) CARD
      GO TO 5000
 5100         LUHOLD = LUB1
              LUB1   = LUB2
              LUB2   = LUHOLD
         REWIND LUB1
 5200 RETURN
 1000 FORMAT ( 20A4 )
 2000 FORMAT ( 1H1, //////////// )
 3100 FORMAT (6X,'*****  ELEMENTS ADDED TO THE DAMAGE BORDERS  *****',
     +        /)
 3200 FORMAT ( 13X, 20A4 )
 3000 FORMAT ( 2A4 )
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE CASEDK ( NROWS )
C     PUT APPROPRIATE LOAD, SPC, MPC, LABEL CARDS INTO CASE CONTROL DECK
      COMMON / CSCTL1 / LOADS, ISPC, IMPC, ILBL
      COMMON / CSCTL2 / XLOAD(40),XSPC(40),XMPC(40),XLBL(20,18)
      COMMON / TEMPRT / IPSW
      COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
      COMMON / UNITS3 / LUC1, LUC2, LUD1, LUD2
      DIMENSION CARD(4), XLINE(80), XROW(20)
      DATA CLOAD, SPC, BLANK, BEGIN / 4HLOAD , 4HSPC= , 1H   , 4HBEGI /
      DATA XLAB1, XLAB2, CMPC / 3HLAB , 3HEL= , 4HMPC= /
         IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT (1H1,'<<<<< ENTRY SUBROUTINE CASEDK >>>>>' )
         IF ( NROWS .EQ. 0 ) PRINT 1500
         REWIND LUC1
         REWIND LUC2
C     ------------------------------------------------------------------
C     LEFT JUSTIFY THE CASE CONTROL DECK
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    5     READ (LUC1,4000,END=50) XLINE
   10     IF ( XLINE(1) .EQ. BLANK ) GO TO 20
      GO TO 40
   20 DO 30 I = 1, 79
              IP1 = I + 1
   30         XLINE(I) = XLINE(IP1)
              XLINE(80) = BLANK
      GO TO 10
   40 CONTINUE
          WRITE (LUC2,4000) XLINE
      GO TO 5
   50 CONTINUE
          REWIND LUC1
          REWIND LUC2
              IHOLD = LUC1
              LUC1  = LUC2
              LUC2  = IHOLD
C     -----------------------------------------------------------------
C     BEGIN READING THE CASE CONTROL DECK
  100     READ (LUC1,1000,END=150) XROW
          IF ( IPSW .GT. 4 ) PRINT 9002, XROW
 9002 FORMAT ('O< < < READ FROM CASE CONTROL AT 100:  ',20A4 )
          IF ( XROW(1) .EQ. CLOAD ) GO TO 200
          WRITE (LUC2,1000) XROW
      GO TO 100
  150     PRINT 4600
 4600 FORMAT ('O*** E R R O R ***', /, 5X, 'NASTRAN CASE CONTROL DECK',
     *          ' CONTAINS NO LOAD CARDS.' )
      RETURN
C     -----------------------------------------------------------------
C     DETERMINE THE CURRENT LOAD CARD VALUE BEING USED
  200     BACKSPACE LUC1
  250     READ ( LUC1,2000) CARD
          IF ( IPSW .GT. 4 ) PRINT 9003, CARD
 9003 FORMAT ('O< < < READ FROM CASE CONTROL AT 250:  ', 1A4, 1A1, 2A4 )
      DO 500  I = 1, LOADS
              IP1 = I + 1
              IM1 = I - 1
              J = 2 * I - 1
              JP1 = 2 * I
              JP2 = J + 2
              JP3 = J + 3
              JM1 = J - 1
              JM2 = J - 2
          IF ( CARD(3) .EQ. XLOAD(J)  .AND.  CARD(4) .EQ. XLOAD(JP1) )
     *GO TO 550
  500 CONTINUE
          PRINT 4500, CARD(3), CARD(4)
 4500 FORMAT (1H1,////,'O*** E R R O R ***',/,5X,'LOAD CARD ',2A4,' IS',
     *          ' NOT ONE OF THE POSSIBLE USER SPECIFIED LOAD CARDS.')
      RETURN
  550 CONTINUE
          IF ( NROWS .GT. 0 ) GO TO 700
C     -----------------------------------------------------------------
C     CHANGE LOAD, SPC, MPC, LABEL CARDS IF NO ELEMENT FAILED
          IF ( I .EQ. LOADS ) GO TO 5250
          IF ( IPSW .GT. 4 ) PRINT 9090
 9090 FORMAT ('O< < < CHANGE CASE CONTROL DECK FOR NO ELEMENTS FAILED')
              CARD(3) = XLOAD(JP2)
              CARD(4) = XLOAD(JP3)
  555     WRITE (LUC2,2000) CARD
          IF ( NROWS .GT. 0 ) PRINT 1200
          PRINT 4800, CARD
          IF ( ISPC .GT. 20 ) GO TO 661
C     $$$$ >20 MEANS THERE ARE NO CHANGES TO SPC CARDS AND THE SPC CARD
C     $$$$ WILL NOT BE AMONG THE LOAD, MPC, OR LABEL CARDS TO BE CHANGED
          READ (LUC1,3500) CARD
          IF ( IPSW .GT. 4 ) PRINT 9004, CARD
 9004 FORMAT ('O< < < READ FROM CASE CONTROL DECK:   ', 4A4 )
          IF ( CARD(1) .EQ. SPC ) GO TO 560
          PRINT 4650
          WRITE (LUC2,3500) CARD
      GO TO 5000
  560 CONTINUE
          IF ( ISPC .EQ. 0 ) GO TO 650
          IF ( NROWS .GT. 0 ) GO TO 750
              CARD(2) = XSPC(JP2)
              CARD(3) = XSPC(JP3)
  650     WRITE (LUC2,3500) CARD
          PRINT 4900, CARD
  661     IF ( IMPC .GT. 20 ) GO TO 656
C     $$$$ >20 MEANS THERE ARE NO CHANGES TO MPC CARDS AND THE MPC CARD
C     $$$$ WILL NOT BE AMONG THE LOAD, SPC, OR LABEL CARDS TO BE CHANGED
          READ (LUC1,3500) CARD
          IF ( IPSW .GT. 4 ) PRINT 9004, CARD
  561     IF ( CARD(1) .EQ. CMPC ) GO TO 562
          PRINT 4651
          WRITE (LUC2,3500) CARD
      GO TO 5000
  562 CONTINUE
          IF ( IMPC .EQ. 0 ) GO TO 564
          IF ( NROWS .GT. 0 ) GO TO 762
              CARD(2) = XMPC(JP2)
              CARD(3) = XMPC(JP3)
  564     WRITE (LUC2,3500) CARD
          PRINT 4900, CARD
  656     IF ( ILBL .GT. 20  .OR.  ILBL .EQ. 0 ) GO TO 5000
C     $$$$ >20 OR =10 MEANS THERE ARE NO CHANGES TO LABEL CARDS AND IT
C     $$$$ WILL NOT BE AMONG THE LOAD, SPC, OR MPC CARDS TO BE CHANGED.
          READ (LUC1,3600) XROW
          IF ( IPSW .GT. 4 ) PRINT 9011, XROW
 9011 FORMAT ('O< < < READ FROM CASE CONTROL DECK:  ',2A3,18A4 )
  655     IF ( XROW(1) .EQ. XLAB1  .AND.  XROW(2) .EQ. XLAB2 ) GO TO 660
          PRINT 4660
          WRITE (LUC2,3600) XROW
      GO TO 5000
  660     IF ( NROWS .GT. 0 ) GO TO 780
      DO 665 K = 1, 18
              KP2 = K + 2
  665         XROW(KP2) = XLBL(IP1,K)
  670     WRITE (LUC2,3600) XROW
          PRINT 4980, XROW
      GO TO 5000
C     -----------------------------------------------------------------
C     RESTORE PREVIOUS LOAD, SPC, AND LABEL CARDS IF ANY ELEMENT FAILED
  700 CONTINUE
          IF ( IPSW .GT. 4 ) PRINT 9091
 9091 FORMAT ('O< < < CHANGE CASE CONTROL DECK FOR FAILED ELEMENTS')
          IF ( J .EQ. 1 ) GO TO 710
              CARD(3) = XLOAD(JM2)
              CARD(4) = XLOAD(JM1)
      GO TO 720
  710         CARD(3) = XLOAD(1)
              CARD(4) = XLOAD(2)
  720 GO TO 555
  750 CONTINUE
          IF ( J .EQ. 1 ) GO TO 760
              CARD(2) = XSPC(JM2)
              CARD(3) = XSPC(JM1)
      GO TO 650
  760         CARD(2) = XSPC(1)
              CARD(3) = XSPC(2)
      GO TO 650
  762 CONTINUE
          IF ( J .EQ. 1 ) GO TO 766
              CARD(2) = XMPC(JM2)
              CARD(3) = XMPC(JM1)
      GO TO 564
  766         CARD(2) = XMPC(1)
              CARD(3) = XMPC(2)
      GO TO 564
  780 CONTINUE
          IF ( J .EQ. 1 ) GO TO 790
      DO 785 K = 1, 18
              KP2 = K + 2
  785         XROW(KP2) = XLBL(IM1,K)
      GO TO 670
  790 DO 795 K = 1, 18
              KP2 = K + 2
  795         XROW(KP2) = XLBL(1,K)
      GO TO 670
 5000 CONTINUE
```

```
C     ----------------------------------------------------------------------
C     COPY REMAINDER OF THE CASE CONTROL DECK
         READ (LUC1,1000,END=5100) XROW
         IF ( IPSW .GT. 5 ) PRINT 9005, XROW
 9005 FORMAT ('0< < < READ FROM CASE CONTROL AT 5000-   ',20A4 )
         WRITE (LUC2,1000) XROW
      GO TO 5000
 5100            LUNOLD = LUC1
                 LUC1   = LUC2
                 LUC2   = LUNOLD
         REWIND LUC1
 5200 RETURN
 5250 CONTINUE
         PRINT 4952
         PRINT 4953
         PRINT 4954
         REWIND LUC1
 5255    READ (LUC1,1000,END=5260) XROW
         PRINT 4955, XROW
         IF ( XROW(1) .EQ. BEGIN ) GO TO 5260
         WRITE (LUC2,1000) XROW
      GO TO 5255
 5260    CONTINUE
                 LUNOLD = LUC1
                 LUC1   = LUC2
                 LUC2 = LUNOLD
         REWIND LUC1
         PRINT 4956
         READ (IABEND)
      RETURN
 1000 FORMAT ( 20A4 )
 1200 FORMAT ( 1H1 )
 1500 FORMAT (1H1,///,6X,'*****  THERE IS NO FAILED ELEMENT  *****')
 2000 FORMAT ( 1A4, 1A1, 2A4 )
 3500 FORMAT ( 4A4 )
 3600 FORMAT ( 2A3, 18A4 )
 4000 FORMAT ( 80A1 )
 4650 FORMAT (//,'0* * *  E R R O R  * * *',/,2X,'THE SPC CARD IS NOT',
     *           ' IN PROPER SEQUENCE IN THE CASE CONTROL DECK'//)
 4651 FORMAT (//,'0* * *  E R R O R  * * *',/,2X,'THE MPC CARD IS NOT',
     *           ' IN PROPER SEQUENCE IN THE CASE CONTROL DECK'//)
 4660 FORMAT (//,'0* * *  E R R O R  * * *',/,2X,'THE LABEL CARD IS',
     *           ' NOT IN PROPER SEQUENCE IN THE CASE CONTROL DECK'//)
 4800 FORMAT (//////////,12X,'THE CASE CONTROL DECK FOR THE NEXT ',
     *           'NASTRAN',/,12X,'ANALYSIS WILL USE THE FOLLOWING NEW ',
     *           'CARDS:',//,12X,1A4,1A1,2A4)
 4900 FORMAT (12X,4A4)
 4950 FORMAT (12X,2A3,18A4)
 4952 FORMAT (1H1,///////,10X,12(2H* ),' N O T I C E  ',12(2H* ),/,10X,
     *'THE PREVIOUS NASTRAN ANALYSIS PRODUCED NO NEW FAILED ELEMENTS',/,
     *10X,'USING THE MOST SEVERE LOADING CONDITION PROVIDED BY THE ',
     *'USER',/,10X,'FOR DATA PROCESSING BY THIS PROGRAM.')
 4953 FORMAT (1H*,47X,'THE CURRENT CASE CONTROL',/,10X,'DECK WILL BE ',
     *'LISTED THEN THIS PROGRAM WILL INTENTIONALLY END',/,10X,
     *'ABNORMALLY BY REMOVING THE "BEGIN BULK" CARD FROM THE CASE', /,
     *10X,'CONTROL DECK TO PREVENT EXECUTION OF SUBSEQUENT COMPUTER ',
     *'JOBS', /,10X, 'IN THIS SERIES.' )
 4954 FORMAT (///,10X,'THE CASE CONTROL DECK USED IN THE PREVIOUS ',
     *'NASTRAN ANALYSIS:',/)
 4955 FORMAT ( 10X, 20A4 )
 4956 FORMAT (1H1,///////,10X,12(2H* ),'INTENTIONAL ABEND ',12(2H* ),//)
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE SEARCH
C     PRIMARY PREPARATION FOR PLOTTING GRID POINT DISPLACEMENTS
C
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
C     TABLE OF VARIABLES:
C
C     LU1        - LOGICAL UNIT NO. OF DISPLACEMENT DATA INPUT
      LU2        - LOGICAL UNIT NO. OF DISPLACEMENT DATA OUTPUT
C     LU3        - LOGICAL UNIT NO. OF GRID POINT DATA INPUT
C     LU4        - LOGICAL UNIT NO. OF GRID POINT DATA OUTPUT
C     ID         - ARRAY OF GRID POINT NUMBERS ALONG A LINE
C     X,Y,Z      - ARRAYS OF X, Y & Z COORDINATES, RESPECTIVELY
C     XD,YD,ZD   - ARRAYS OF X, Y & Z DISPLACEMENTS, RESPECTIVELY
C     LEN        - ARRAY OF LENGTHS BETWEEN GRID POINTS ALONG A LINE
C     NDISPN     - NUMBER OF NODES WITH DISPLACEMENTS
C     NGDN       - NO. OF GRID POINTS IN NASTRAN DATA (USUALLY = NDISPN)
C     SUBCAS     - SUBCASE TITLE NUMBER ( FROM DISPLACEMENT DATA )
C     HEADER     - TITLE FOR PLOTING AND PAGE HEADING
C     NPPL       - NUMBER OF GRID POINTS PER LINE
C     NUMSUB     - SUBCASE NUMBER TO BE SEARCHED FOR DISPLACEMENTS
C     NPLT       - X, Y, Z, 1, 2 OR 3 OR ANY COMBINATION USED TO SPECIFY
C                  WHICH SET(S) OF COORDINATES TO PLOT.
C
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C
      REAL LEN
C     THE DIMENSION ON IID CONTROLS THE NUMBER OF NODES WHICH CAN BE
C     INPUT FOR PLOTTING PURPOSES:  NUMBER OF NODES = ( DIMENSION / 8 )
      COMMON / CTLRD1 / ICNTF2, ICNTGF, ICNTSF, NBULK, NDISPN, NGDN
      COMMON / CTLRD2 / IFLAG,NFS,NSUB,NUMBR(20),STRMEM(3,4),STRPLT(3,4)
      COMMON / TEMPRT / IPSW
      COMMON / GRIDPT / KODE, ID(8)
      COMMON / PLOTS  / NPPL, HEADER(40), NPLT(5), HEADPR(122),SUBCAS(7)
      COMMON / PLTDTA / LEN(50), XD(50), YD(50), ZD(50), XXX(50)
      COMMON / UNITS1 / LU1, LU2, LU3, LU4, LUNAS, IR
      DIMENSION IID(120), IN(8), X(50), Y(50), Z(50)
      INTEGER BLANK / 1H  /
      DATA STAR / 1H* /
C     FUNCTION TO DEFINE LINE LENGTH
      XLN(X1,Y1,Z1,X2,Y2,Z2) = SQRT((X2-X1)**2+(Y2-Y1)**2+(Z2-Z1)**2)
         IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT ('0<<<<< ENTRY SUBROUTINE SEARCH >>>>>' )
         IF ( ICNTGF .EQ. 1 ) GO TO 10
         IF ( IPSW .GT. 3 ) PRINT 9005
 9005 FORMAT('0<<< CALL SUBROUTINE GPFILE FROM SUBROUTINE SEARCH >>>')
      CALL GPFILE
         IF ( IPSW .GT. 3 ) PRINT 9006
 9006 FORMAT('0<<< RETURN TO SUBROUTINE SEARCH FROM SUBROUTINE GPFILE')
         IF ( KODE .NE. 0 )   RETURN
   10    READ (IR,1010,END=150) HEADER
         IF ( HEADER(1) .EQ. STAR .AND. HEADER(2) .EQ. STAR ) RETURN
         IF ( IPSW .GT. 3 ) PRINT 9007
 9007 FORMAT('0<<< CALL SUBROUTINE CENTER FROM SUBROUTINE SEARCH >>>')
      CALL CENTER
         IF ( IPSW .GT. 3 ) PRINT 9008
 9008 FORMAT('0<<< RETURN TO SUBROUTINE SEARCH FROM SUBROUTINE CENTER')
         READ 1030, NPPL, NUMSUB, NRIG, LOC, NPLT
             NGRID = 8 * NPPL
         READ 1001, ( IID(N), N = 1,NGRID )
             NPLOT = 0
      PRINT 2030
      PRINT 2040, HEADPR
      PRINT 2000
      DO 20 I = 1, 50
                X(I) = 0.0
                Y(I) = 0.0
                Z(I) = 0.0
                XD(I) = 0.0
                YD(I) = 0.0
                ZD(I) = 0.0
                LEN(I) = 0.0
   20 CONTINUE
      REWIND LU2
      REWIND LU4
                NPTS = 0
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     SET UP GRID POINT COORDINATES
   30    READ (LU4,END=60) ID, XX, YY, ZZ
      DO 40 N = 1, NPPL
               IN(1) = 8 * N - 7
      DO 42  J = 2, 8
               JM1 = J - 1
               IN(J) = IN(JM1) + 1
   42 CONTINUE
      DO 44  J = 1, 8
         IF (  IID( IN(J) ) .NE. ID(J)  ) GO TO 40
```

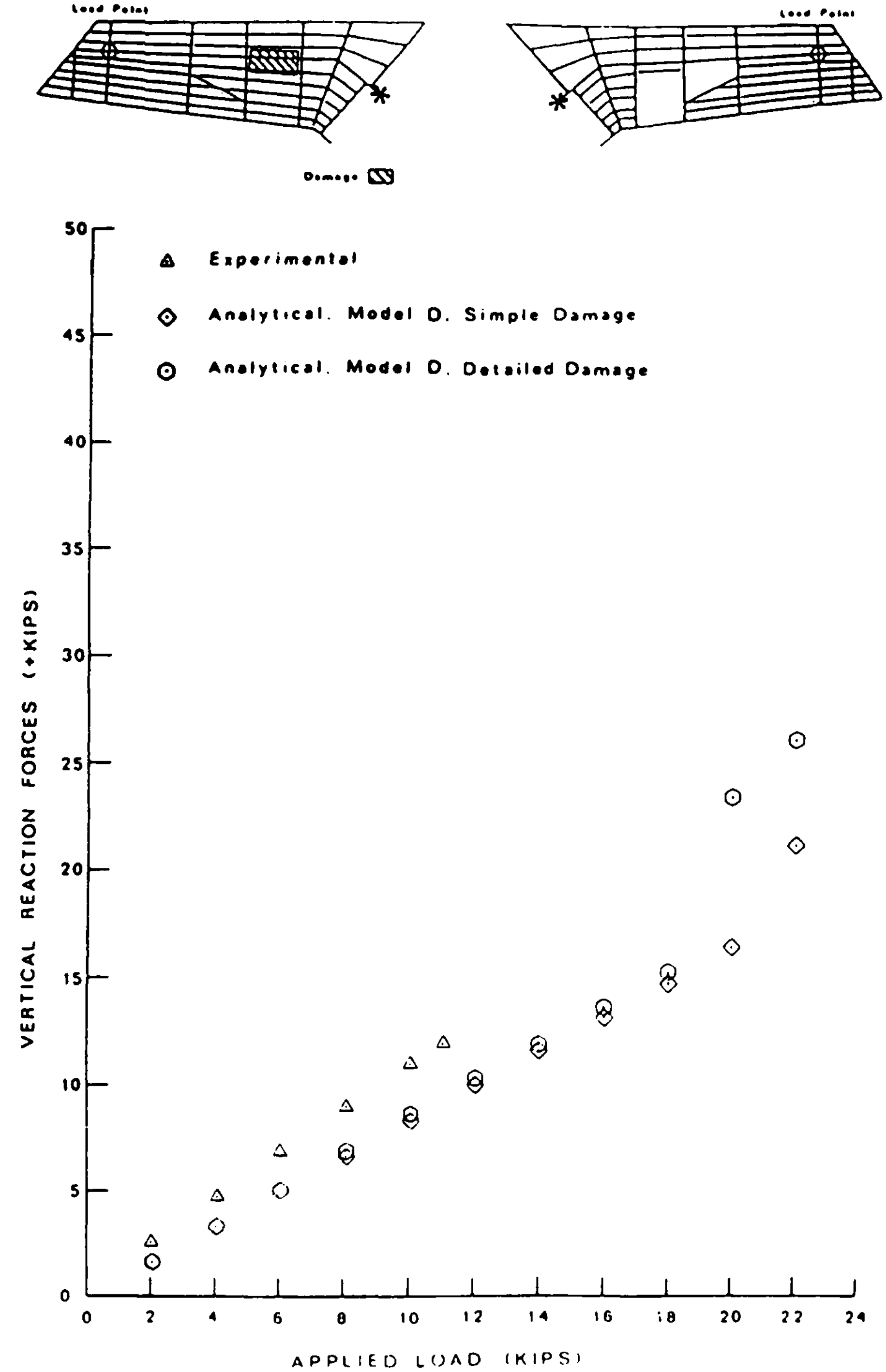
```
   44 CONTINUE
      GO TO 50
   40 CONTINUE
         GO TO 30
   50          X(N) = XX
               Y(N) = YY
               Z(N) = ZZ
               NPTS = NPTS + 1
         IF ( NPTS .LT. NPPL ) GO TO 30
   60    IF ( NPTS .NE. NPPL ) GO TO 900
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     CALCULATE LENGTHS
               NP1 = NPPL - 1
      DO 70 I = 1, NP1
               J = I + 1
               LEN(I) = XLN ( X(I), Y(I), Z(I), X(J), Y(J), Z(J) )
   70 CONTINUE
         IF ( NUMSUB .EQ. 1 ) GO TO 90
         IF ( NUMSUB .GT. NSUB ) GO TO 920
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     POSITION FILE TO BEGINNING OF DESIRED SUBCASE
               NR = ( NUMSUB - 1 ) * ( NDISPN + 1 )
      DO 80 I = 1, NR
         READ (LU2,END=930)
   80 CONTINUE
   90    READ (LU2,END=930) SUBCAS
               NPTS = 0
               NGRID = 0
  100    READ (LU2,END=930) ID, XX, YY, ZZ, U, V, W
               NGRID = NGRID + 1
      DO 110 I = 1, NPPL
              IN(1) = 8 * I - 7
      DO 112  J = 2, 8
              JM1 = J - 1
              IN(J) = IN(JM1) + 1
  112 CONTINUE
      DO 114  J = 1, 8
         IF (  IID( IN(J) ) .NE. ID(J)  ) GO TO 110
  114 CONTINUE
      GO TO 120
  110 CONTINUE
         IF ( NGRID .LT. NDISPN ) GO TO 100
         GO TO 910
  120          XD(I) = XX
               YD(I) = YY
               ZD(I) = ZZ
               NPTS = NPTS + 1
         IF ( NPTS .LT. NPPL ) GO TO 100
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     PRINT OUT RESULTS
      DO 130 I = 1, NPPL
              IN(1) = 8 * I - 7
      DO 132  J = 2, 8
              JM1 = J - 1
              IN(J) = IN(JM1) + 1
  132 CONTINUE
      PRINT 2010, (IID( IN(J) ),J=1,8),X(I),Y(I),Z(I),XD(I),YD(I),ZD(I)
         IF ( I .EQ. NPPL ) GO TO 130
      PRINT 2020, LEN(I)
  130 CONTINUE
      DO 140 I = 1, 5
         IF ( NPLT(I) .EQ. BLANK ) GO TO 140
              NPLOT = 1
  140 CONTINUE
         IF ( NPLOT.NE.0 .AND. IPSW.GT.2 ) PRINT 9009
 9009 FORMAT('0<<< CALL SUBROUTINE PLOT FROM SUBROUTINE SEARCH >>>')
         IF ( NPLOT .NE. 0 ) CALL PLOT
         IF ( NPLOT.NE.0 .AND. IPSW.GT.3 ) PRINT 9011
 9011 FORMAT('0<<< RETURN TO SUBROUTINE SEARCH FROM SUBROUTINE PLOT >>')
         GO TO 10
  150 PRINT 2030
      RETURN
  900 PRINT 4010
         GO TO 10
  910 PRINT 4000
         GO TO 10
  920 PRINT 4020
         GO TO 10
  930 PRINT 4030
         GO TO 10
 1000 FORMAT ( 16I5 )
 1001 FORMAT ( 72A1 )
 9002 FORMAT ( 4(  2X, 8A1 )  )
 1010 FORMAT ( 80A1 )
 9003 FORMAT(1H0,'< < <  ',80A1, '  > > >')
 1030 FORMAT ( 3I5, 4X, A1, 5A1 )
 9004 FORMAT(1H0,'< < < ',3I5,4X,A1,5A1,'  > > >')
 2000 FORMAT(1H ,20X,'GRID ID.',3X,'LENGTH',4X,'X-COORD',4X,'Y-COORD',
     + 4X,'Z-COORD',5X,'X-DISP',5X,'Y-DISP',5X,'Z-DISP',//)
 2010 FORMAT(1H ,21X,8A1,10X, 6(4X,F7.3))
 2020 FORMAT(1H ,29X,F7.2)
 2030 FORMAT ( 1H1, ///////////// )
 2040 FORMAT ( 2X, 122A1, // )
 3000 FORMAT ( 2I5, 4X, A1, I5 )
 3010 FORMAT ( I5, 7X, 1PE13.6, 2X, 1PE13.6, 2X, 1PE13.6, 2X, 1PE13.6 )
 4000 FORMAT ( 41H-***ERROR***  GRID POINT SPECIFIED NOT IN          /
     +     14X, 48HNASTRAN DISPLACEMENT OUTPUT. NEW LINE ATTEMPTED.    )
 4010 FORMAT ( 41H-***ERROR***  GRID POINT SPECIFIED NOT IN          /
     +     14X, 49HNASTRAN GRID POINT DATA DECK. NEW LINE ATTEMPTED.   )
 4020 FORMAT ( 70H-***ERROR***  SUBCASE SPECIFIED EXCEEDS NO. OF SUBCASE
     +S IN OUTPUT DATA  / 14X, 35HREQUEST IGNORED. WILL TRY NEW LINE.  )
 4030 FORMAT ( 47H-***ERROR***  END OF FILE REACHED UNEXPECTEDLY. /
     +           14X, 18HWILL TRY NEW LINE. )
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE GPFILE
C     SET UP GRID POINT FILE FOR PLOTS
      COMMON / CTLRD1 / ICNTF2, ICNTGF, ICNTSF, NBULK, NDISPN, NGDN
      COMMON / TEMPRT / IPSW
      COMMON / GRIDPT / KODE, ID(8)
      COMMON / UNITS1 / LU1, LU2, LU3, LU4, LUNAS, IR
      INTEGER BLANK / 1H  /
         IF ( IPSW .GT. 0 ) PRINT 9003
 9003 FORMAT ('0<<<<< ENTRY SUBROUTINE GPFILE >>>>>' )
      DO 10 N = 1, NGDN
         READ (LU3,1000,END=20) ID, X, Y, Z
  100    IF ( ID(1) .EQ. BLANK ) GO TO 200
      GO TO 400
  200 DO 300  I = 1, 7
              IP1 = I + 1
  300         ID(I) = ID(IP1)
              ID(8) = BLANK
      GO TO 100
  400 CONTINUE
      WRITE (LU4) ID, X, Y, Z
   10 CONTINUE
      RETURN
   20 PRINT 1010
      BACKSPACE LU4
         READ(LU4) ID, X, Y, Z
      PRINT 1020, N, ID, X, Y, Z
              KODE = 1
      RETURN
 1000 FORMAT ( 8X, 8A1, 8X, 3E8.0 )
 9001 FORMAT(1H1,19X,'GRID POINT FILE',//,
     +3X,'GRID ID.',7X,'X-COOR.',8X,'Y-COOR.',8X,'Z-COOR.')
 9002 FORMAT(1H ,1X, 8A1,3(8X,F10.4))
 1010 FORMAT('0*****  ERROR  *****  END OF FILE ON GRID POINT FILE')
 1020 FORMAT('0RECORD:  ',I5,5X,'GP ID =',8A1,3(8X,F10.4))
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE PLOT
C     EXECUTIVE ROUTINE TO CONTROL SUBROUTINES SCAXIS AND PLT20A
      REAL LEN
      DIMENSION WN(6)
      COMMON / TEMPRT / IPSW
      COMMON / PLOTS  / NPPL, HEADER(40), NPLT(5), HEADPR(122),SUBCAS(7)
      COMMON / PLTDTA / LEN(50), XD(50), YD(50), ZD(50), XX(50)
```

```
      DATA NN / 1HX, 1HY, 1HZ, 1H1, 1H2, 1H3 /
          IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT ('0<<<<< ENTRY SUBROUTINE PLOT >>>>>' )
                XX(1) = 0.0
      DO 10 N = 2, NPPL
                XX(N) = XX(N-1) + LEN(N-1)
   10 CONTINUE
                NX = 0
                NY = 0
                NZ = 0
               DMAX = XX(NPPL)
               DMIN = 0.0
                NPP = 0
      DO 40 I = 1, 5
      DO 20 J = 1, 6
          IF ( NPLT(I) .EQ. NN(J) ) GO TO 30
   20 CONTINUE
          GO TO 40
   30     IF ( J .EQ. 1 .OR. J .EQ. 4 ) NX = 1
          IF ( J .EQ. 2 .OR. J .EQ. 5 ) NY = 1
          IF ( J .EQ. 3 .OR. J .EQ. 6 ) NZ = 1
   40 CONTINUE
                NG = 10
      CALL SCAXIS ( XX, DMIN, DMAX, XMIN, XMAX, NG )
          IF ( NX .EQ. 0 ) GO TO 50
      CALL SCAXIS ( XD, DMIN, DMAX, YMIN, YMAX, NG )
      CALL PLT20A ( XX, XD, XMAX, XMIN, YMAX, YMIN )
      PRINT 1000, HEADPR, SUBCAS
   50     IF ( NY .EQ. 0 ) GO TO 60
      CALL SCAXIS ( YD, DMIN, DMAX, YMIN, YMAX, NG )
      CALL PLT20A ( XX, YD, XMAX, XMIN, YMAX, YMIN )
      PRINT 1010, HEADPR, SUBCAS
   60     IF ( NZ .EQ. 0 ) GO TO 70
      CALL SCAXIS ( ZD, DMIN, DMAX, YMIN, YMAX, NG )
      CALL PLT20A ( XX, ZD, XMAX, XMIN, YMAX, YMIN )
      PRINT 1020, HEADPR, SUBCAS
   70 RETURN
 1000 FORMAT ( 5X, 122A1, /, 33X,
     *          'PLOT OF DISPLACEMENT IN THE X DIRECTION:  ', 7A4 )
 1010 FORMAT ( 5X, 122A1, /, 33X,
     *          'PLOT OF DISPLACEMENT IN THE Y DIRECTION:  ', 7A4 )
 1020 FORMAT ( 5X, 122A1, /, 33X,
     *          'PLOT OF DISPLACEMENT IN THE Z DIRECTION:  ', 7A4 )
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE CENTER
C     BUILD AND CENTER THE HEADING FOR PLOTS
      COMMON / TITLE  / RUN(72)
      COMMON / PLOTS  / NPPL, HEADER(40), NPLT(5), HEADPR(122),SUBCAS(7)
      DIMENSION TEMP(123)
      DATA BLANK, COLON / 1H , 1H: /
C         IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT ('0<<<<< ENTRY SUBROUTINE CENTER >>>>>' )
                IC = 0
                ICHL = 0
                ICHF = 0
                ICRF = 0
                ICRL = 0
                IDIFH = 0
                IDIFR = 0
      DO 20 I = 1, 40
          IF ( HEADER(I) .NE. BLANK ) GO TO 30
   20 CONTINUE
          GO TO 70
   30           ICHF = I
   40 DO 50 I = 1, 40
                J = 41 - I
          IF ( HEADER(J) .NE. BLANK ) GO TO 60
   50 CONTINUE
          GO TO 70
   60           ICHL = J
                IDIFH = ICHL - ICHF
   70 DO 80 I = 1, 72
          IF ( RUN(I) .NE. BLANK  ) GO TO 90
   80 CONTINUE
          GO TO 120
   90           ICRF = I
      DO 100 I = 1, 72
                J = 73 - I
          IF ( RUN(J) .NE. BLANK ) GO TO 110
  100 CONTINUE
  110           ICRL = J
  120           IDIFR = ICRL - ICRF
                J = 0
          IF ( IDIFH .EQ. 0 .AND. IDIFR .EQ. 0 ) GO TO 180
          IF ( IDIFH .EQ. 0 ) GO TO 140
      DO 130 I = ICHF, ICHL
                J = J + 1
                TEMP(J ) = HEADER(I)
  130 CONTINUE
          IF ( IDIFR .EQ. 0 ) GO TO 160
                IC = 2
                J = J + 1
                TEMP(J) = COLON
                J = J + 1
                TEMP(J) = BLANK
  140 DO 150 I = ICRF, ICRL
                J = J + 1
                TEMP(J) = RUN(I)
  150 CONTINUE
  160           NUM = IDIFH + IDIFR + IC + 2
                IF = ( 122 - NUM ) / 2
      DO 170 I = 1, 122
                HEADPR(I) = BLANK
  170 CONTINUE
      DO 175 I = 1,NUM
              HEADPR(IF+I) = TEMP(I)
  175 CONTINUE
  180 RETURN
      END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
      SUBROUTINE SCAXIS (V,VMIN,VMAX,SMIN,SMAX,NG )
C
C     ...................................................................
C     .                                                                 .
C     .   THIS IS A ROUTINE WHICH WILL SELECT A SCALE FOR DATA TO BE    .
C     .    PLOTTED. THE USER MAY EITHER SUPPLY THE DATA TO BE SCALED    .
C     .    OR THE MINIMUM AND MAXIMUM DATA VALUES. IN ADDITION, THE     .
C     .    USER SPECIFIES THE NUMBER OF INCREMENTS TO APPEAR ON THE     .
C     .    AXIS AND A SET OF ALLOWABLE INCREMENT VALUES.                .
C     .                                                                 .
C     .   V    : THE VECTOR OF DATA TO BE SCALED.                       .
C     .   NPPL : THE NUMBER OF POINTS IN V TO BE SCALED. IF NPPL IS     .
C     .           ZERO, THEN THE ROUTINE ASSUMES THAT VMIN AND VMAX     .
C     .           CONTAIN THE MINIMUM AND MAXIMUM OF THE DATA AND V IS  .
C     .           NOT TO BE SEARCHED.                                   .
C     .   VMIN : THE MINIMUM DATA VALUE                                 .
C     .   VMAX : THE MAXIMUM DATA VALUE                                 .
C     .   SMIN : THE SCALED MINIMUM VALUE. SMIN .LE. VMIN               .
C     .   SMAX : THE SCALED MAXIMUM VALUE. SMAX .GE. VMAX               .
C     .   NG   : THE NUMBER OF INCREMENTS TO APPEAR ON THE SCALED AXIS  .
C     .                                                                 .
C     .   IN ADDITION, AN INTEGER ARRAY CALLED "ALLOW" CONTAINS THE     .
C     .    ALLOWABLE SCALING VALUES. THESE MAY BE CHANGED TO GIVE A     .
C     .    DIFFERENT SET OF VALUES BY SPECIFING NEW VALUES AND PLACING  .
C     .    THEM IN A COMMON ARRAY CALLED /ALLOWB/ ( MAXIMUM OF 20       .
C     .    VALUES ).                                                    .
C     .                                                                 .
C     ...................................................................
C
      COMMON / TEMPRT / IPSW
      COMMON / PLOTS  / NPPL, HEADER(40), NPLT(5), HEADPR(122),SUBCAS(7)
      DIMENSION V(1)
      INTEGER ALLOW(9) / 1, 2, 3, 4, 5, 6, 7, 8, 9 /, NA / 9 /
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     SEARCH FOR VMIN AND VMAX IF NEEDED
          IF ( IPSW .GT. 0 ) PRINT 9001
 9001 FORMAT ('0<<<<< ENTRY SUBROUTINE SCAXIS FROM SUBROUTINE PLOT >>') 
```

```
      IF ( NPPL .EQ. 0 ) GO TO 20
              VMIN = V(1)
              VMAX = V(1)
   DO 10 I = 2, NPPL
              VMIN = AMIN1 ( VMIN, V(I) )
              VMAX = AMAX1 ( VMAX, V(I) )
 10 CONTINUE
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C  SCALE (VMAX-VMIN)/NG TO HAVE SAME NO. DIGITS AS NO  ENTRIES IN ALLOW
 20           ND = IFIX (  1.01 + ALOG10 ( FLOAT( ALLOW(1) ) ) )
              VINC = ( VMAX - VMIN ) / NG
              A = ALOG10 ( VINC )
              I = A
      IF ( A .LT  0.0 ) I = I - 1
              SCALE = 10.0 ** ( ND - 1 - I )
              VINC = VINC * SCALE
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     FIND AN ELEMENT IN ALLOW THAT IS GREATER THAN OR EQUAL TO VINC
   DO 30 I = 1, NA
              A = ALLOW(I)
      IF ( A  GE  VINC ) GO TO 50
 30 CONTINUE
 40           I = 1
              A = ALLOW(1)
              SCALE = SCALE / 10.0
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     THE SMALLEST ALLOWABLE INCREMENT IS NOW A / SCALE.
C      NOW PICK SMIN AND SMAX SO ZERO WILL BE AN INCREMENT VALUE.
 50           VINC = A / SCALE
              A = VMIN / VINC
              J = A
      IF ( A  LT. 0.0 ) J = J - 1
              SMIN = J * VINC
              SMAX = SMIN + VINC * NG
              IF ( SMAX .GE. VMAX ) GO TO 60
C     - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C     VINC IS TOO SMALL TO FIT THE ADJUSTED RANGE. INCREASE IT
      IF ( I  EQ. NA ) GO TO 40
              I = I + 1
              A = ALLOW(I)
      GO TO 50
 60 RETURN
    END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
    SUBROUTINE PLT20A ( X, Y, XMAX, XMIN, YMAX, YMIN )
C
C
C
C       SUBROUTINE TO PRODUCE A PRINTER PLOT OF X VS  Y
C       X AND Y ARE ROUNDED ( NOT TRUNCATED ) TO THE NEAREST
C       INTEGERS BEFORE PLOTTING. GRID SIZE IS 10 X 10.
C
C       X       ARRAY OF X COORDINATES
C       Y       ARRAY OF Y COORDINATES
C       NPPL    NUMBER OF POINTS IN X AND Y
C       XMAX    MAXIMUM X VALUE
C       XMIN    MINIMUM X VALUE
C         IF XMAX = XMIN, X WILL BE SEARCHED TO FIND THE MINIMUM
C         AND MAXIMUM VALUES
C       YMAX    MAXIMUM Y VALUE
C       Y MIN   MINIMUM Y VALUE
C         IF YMAX = YMIN, Y WILL BE SEARCHED TO FIND THE MINIMUM
C         AND MAXIMUM VALUES
C
C                     . . . . . . . . . . . . . . . . . . . . . . . . .
C
    COMMON / TEMPRT / IPSW
    COMMON / PLOTS  / NPPL, HEADER(40), NPLT(5), HEADPR(122),SUBCAS(7)
    DIMENSION IFX(101), ZX(11), X(1), Y(1)
    DATA IBLNK, ISTAR / 1H , 1H* /
    DATA IYMAX / 50 /, J1 / 1 /
      IF ( IPSW  GT. 0 ) PRINT 9001
9001 FORMAT ('0<<<<< ENTRY SUBROUTINE PLT20A FROM SUBROUTINE PLOT >>')
              LINE = 5
              XL = XMAX
              YL = YMAX
              XS = XMIN
              YS = YMIN
         IF ( XMAX .NE. XMIN ) GO TO 20
              XL = X(1)
              XS = X(1)
    DO 10 N = 2, NPPL
              XL = AMAX1 ( X(N), XL )
              XS = AMIN1 ( X(N), XS )
 10 CONTINUE
 20      IF ( YMAX .NE. YMIN ) GO TO 40
              YL = Y(1)
              YS = Y(1)
    DO 30 N = 2, NPPL
              YL = AMAX1 ( Y(N), YL )
              YS = AMIN1 ( Y(N), YS )
 30 CONTINUE
 40           XSCALE = ( XL - XS ) * 0.01
              YSCALE = ( YL - YS ) / FLOAT ( IYMAX )
    PRINT 200
    PRINT 210
              LL = IYMAX
         GO TO 60
 50           LL = LL - 1
 60 DO 70 I = 1, 101
              IFX(I) = IBLNK
 70 CONTINUE
    DO 90 I = J1, NPPL
         IF ( X(I) .GT. XL .OR. X(I) .LT. XS ) GO TO 90
         IF ( Y(I) .GT. YL .OR. Y(I) .LT. YS ) GO TO 90
              IY = ( Y(I) - YS ) / YSCALE + 0.5
         IF ( IY - LL ) 90, 80, 90
 80           IX = ( X(I) - XS ) / XSCALE + 0.5
              II = IX + 1
              IFX(II) = ISTAR
 90 CONTINUE
              ZY = FLOAT ( LL ) * YSCALE + YS
         IF ( LINE .EQ. 5 ) PRINT 220, ZY, ( IFX(I), I = 1, 101 )
         IF ( LINE .NE. 5 ) PRINT 240, ( IFX(I), I = 1, 101 )
              LINE = LINE + 1
         IF ( LINE .GT. 5 ) LINE = 1
         IF ( LL .NE. 0 ) GO TO 50
    PRINT 210
    DO 100 K = 1, 11
              ZX(K) = 10. * FLOAT ( K - 1 ) * XSCALE + XS
100 CONTINUE
    PRINT 230, ( ZX(K), K = 1, 11 )
    PRINT 220
    RETURN
200 FORMAT ( 1H1, ///// )
210 FORMAT ( 15X, 20 ( 5H¦.... ), 1H¦ )
220 FORMAT ( 1H , F8.3, 4X, 2H-¦, 101A1, 1H¦ )
230 FORMAT ( 9X, 11 ( 2X, F8.3 ) )
240 FORMAT ( 14X, 1H¦, 101A1, 1H¦ )
    END
C
C
C <><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><><>
    BLOCK DATA
C   CORRELATES THE ASSIGNMENT OF FILE DESIGNATION NUMBERS, ELEMENT
C   ID NUMBERS, AND NUMBER OF ITEMS OF NASTRAN OUTPUT FOR EACH
C   ELEMENT TYPE ACCEPTED BY PROSCAN.  ALSO ASSIGNS ALL OTHER FILE
C   DESIGNATION NUMBERS FOR PROGRAM EXECUTION.
    COMMON / CTLDTA / LTYPE(18), NUM(18)
    COMMON / DTANAS / STRE, SUBC1, SUBC2
    COMMON / UNITS1 / LU1, LU2, LU3, LU4, LUNAS, IR
    COMMON / UNITS2 / LUB1, LUB2, LUF1, LUF2, LUGP, LU(18)
    COMMON / UNITS3 / LUC1, LUC2, LUD1, LUD2
    DATA STRE, SUBC1, SUBC2 / 4H STR, 4HSSUB, 4HCASE /
    DATA LTYPE/10,16,62,63,15,19,18, 1, 4, 7, 6,17, 9, 8, 3, 5,34,12/
    DATA NUM  / 4, 7, 7, 7,16,16,16, 4, 3,16,16,16, 7,16, 4, 3,15, 1/
    DATA LU   /11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28/
    DATA  LU1,  LU2,  LU3,  LU4,  LUNAS, IR /  1, 2,41, 4,44, 5 /
    DATA  LUB1, LUB2, LUF1, LUF2, LUGP       / 42,36,31,32,35    /
    DATA  LUC1, LUC2, LUD1, LUD2             / 43,37,33,34       /
    END
```

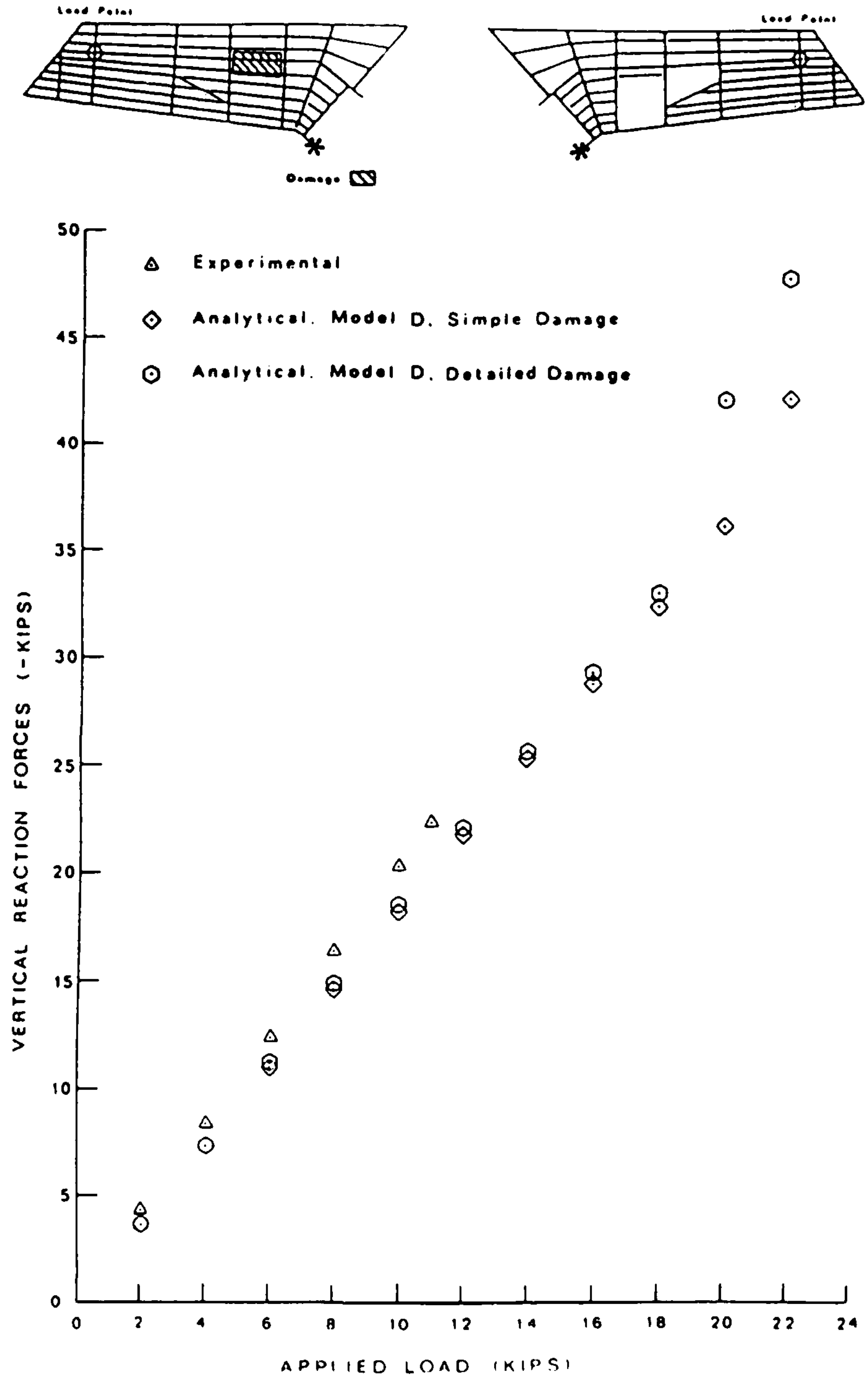
APPENDIX I

PLOTS OF ANALYTICAL AND EXPERIMENTAL DATA



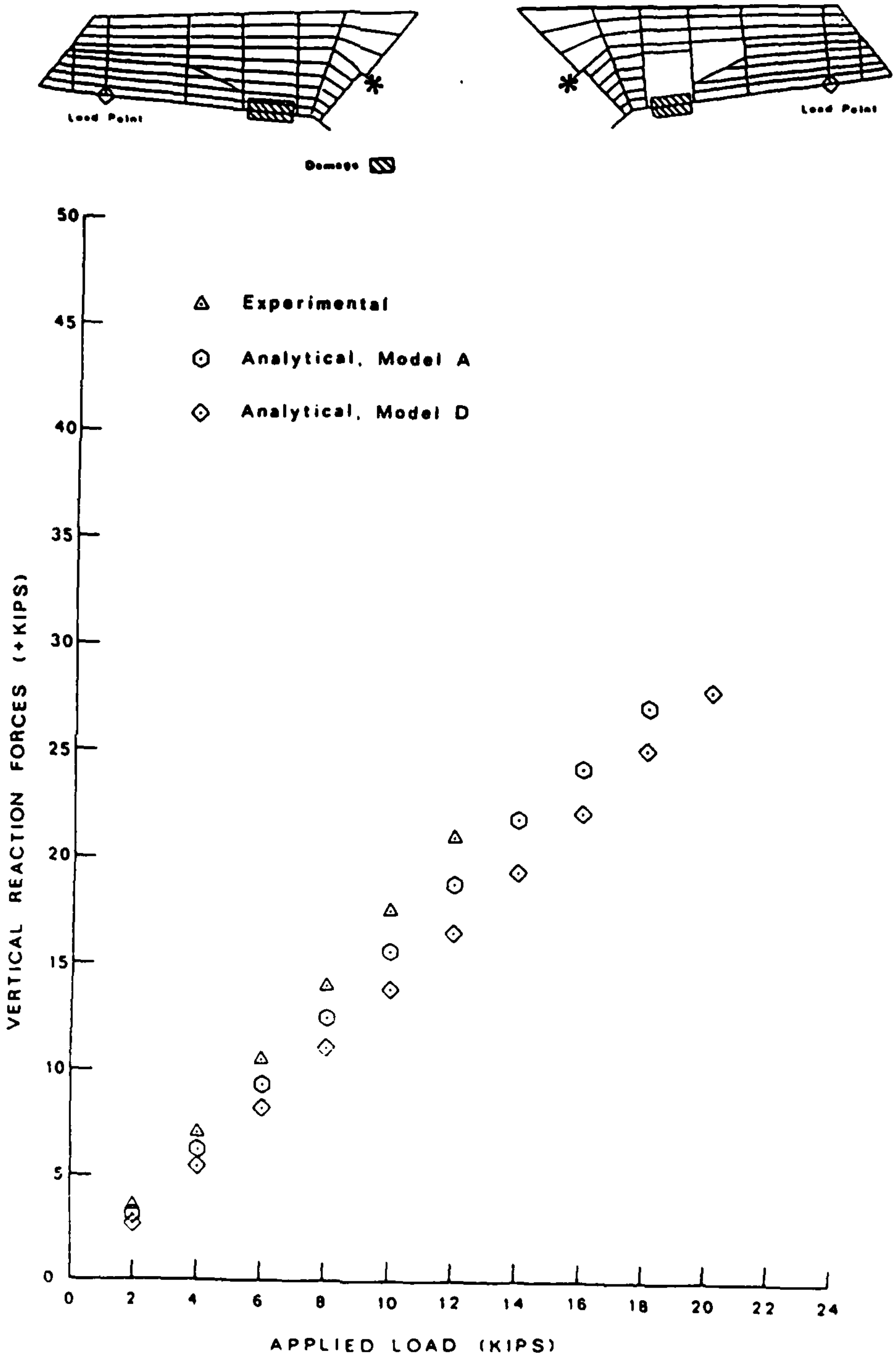
(a) Test 1, Front Spar

Figure 26. Comparison of Vertical Reaction Forces



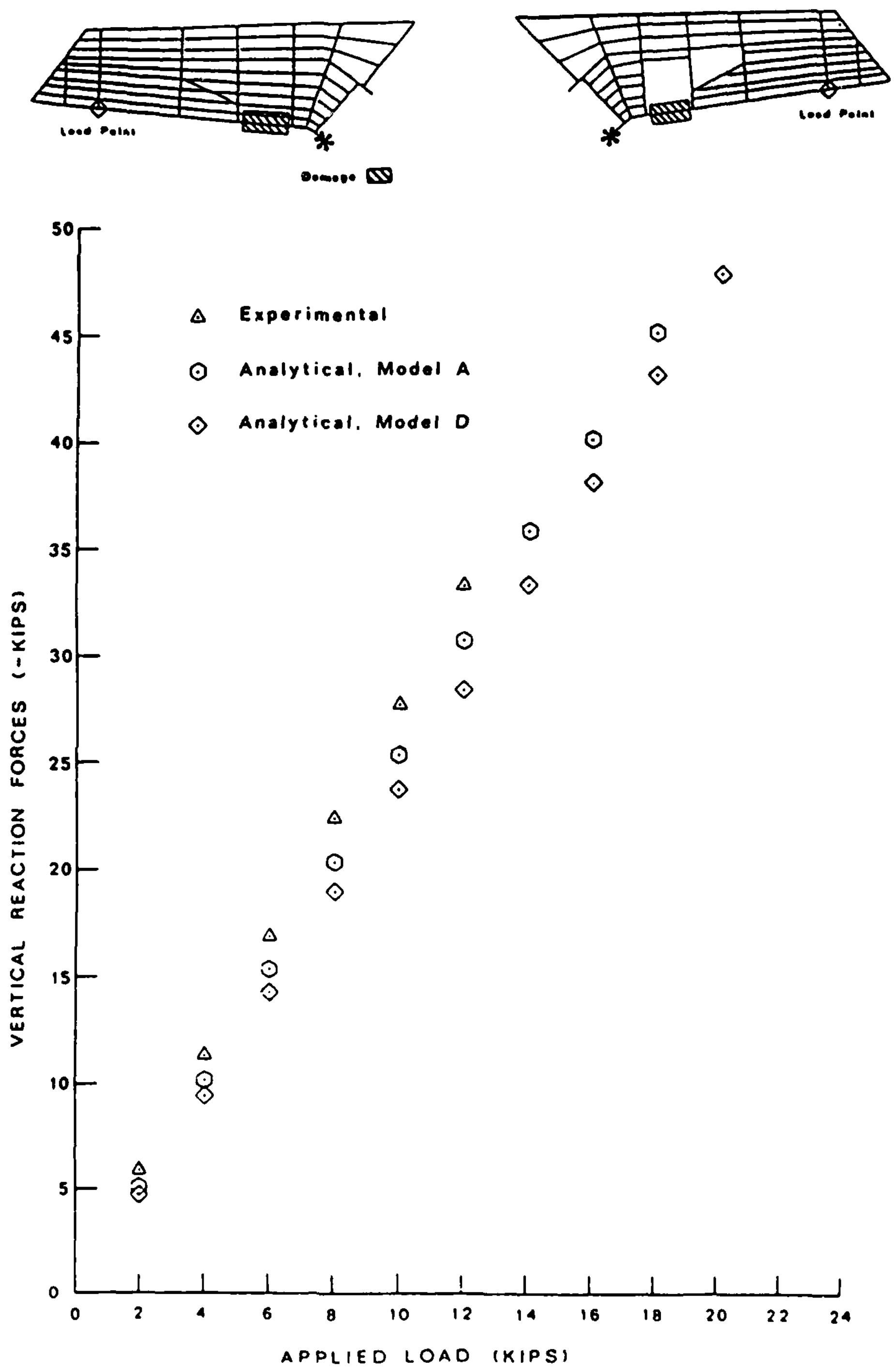
(b) Test 1, Rear Spar

Figure 26. (Continued)



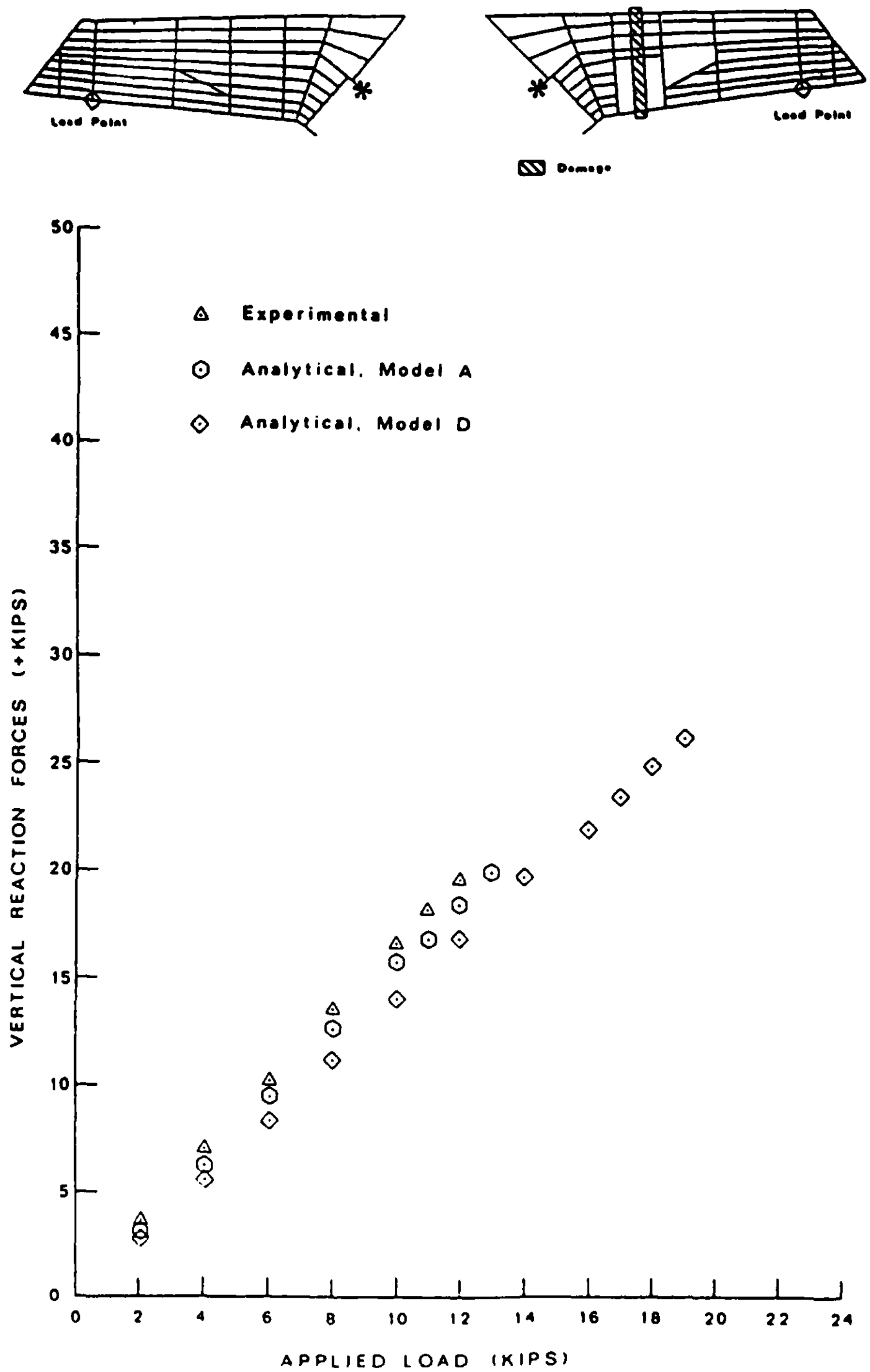
(c) Test 2C, Front Spar

Figure 26. (Continued)



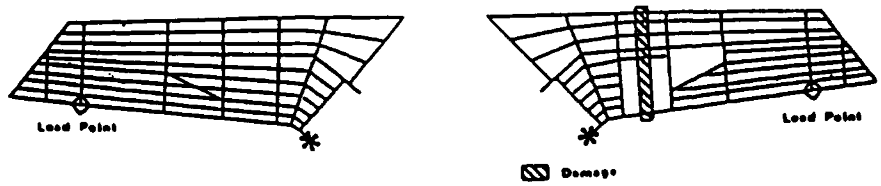
(d) Test 2C, Rear Spar

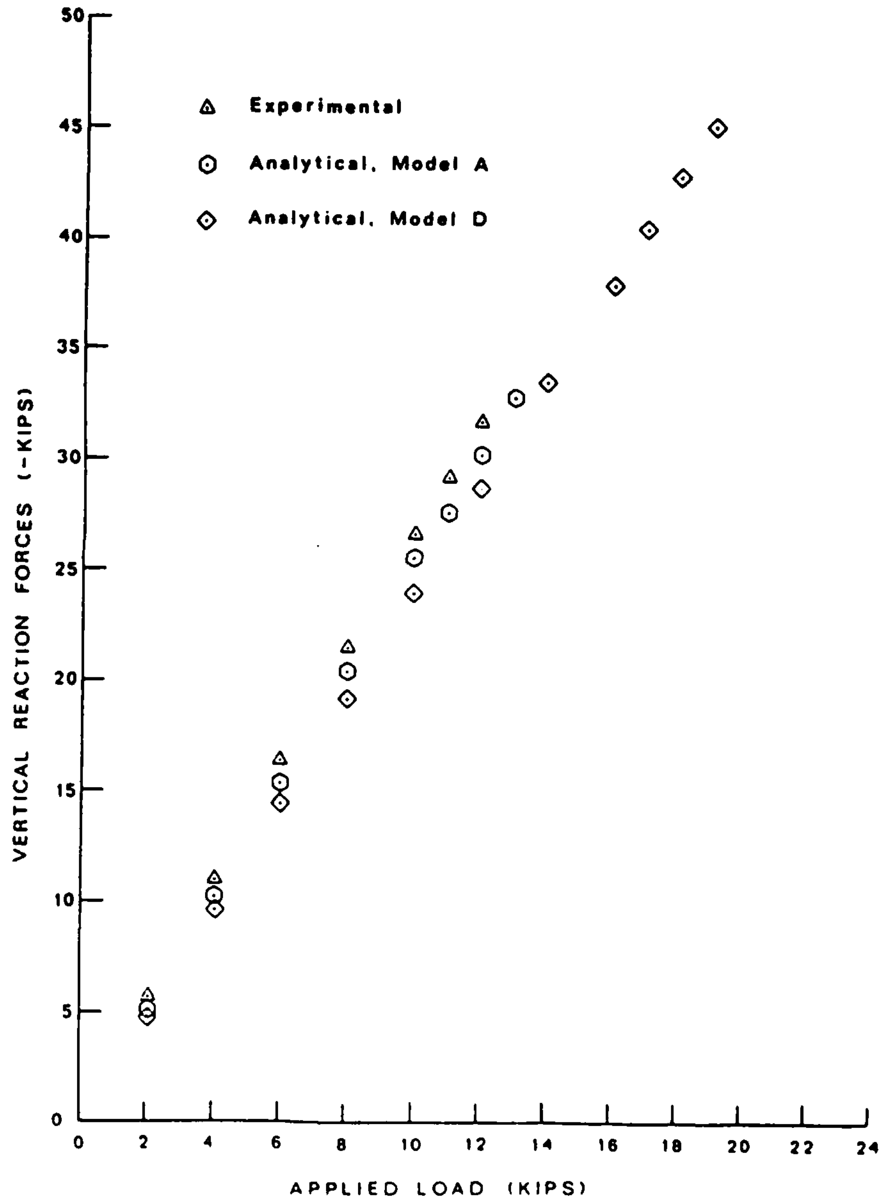
Figure 26. (Continued)



(e) Test 3B, Front Spar

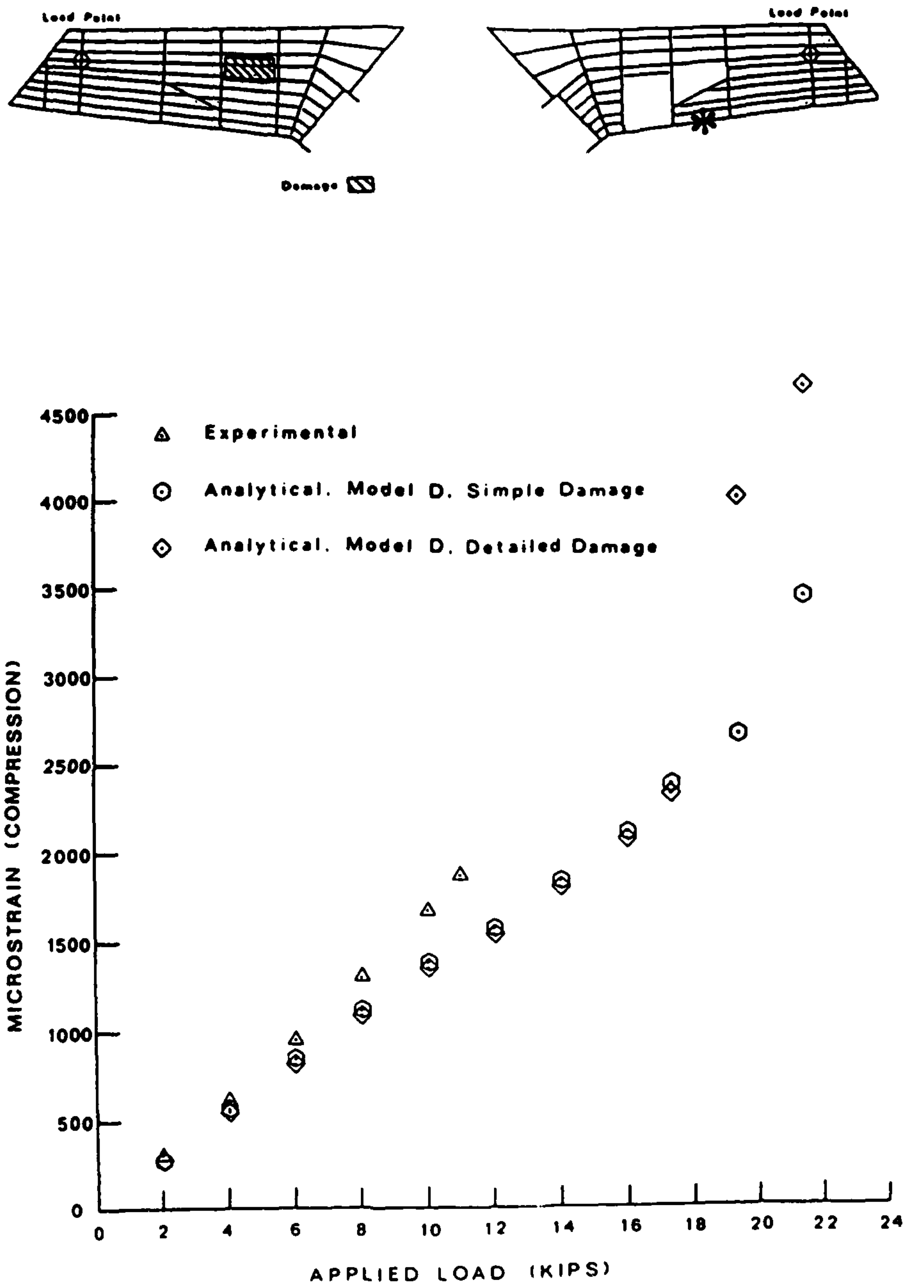
Figure 26. (Continued)





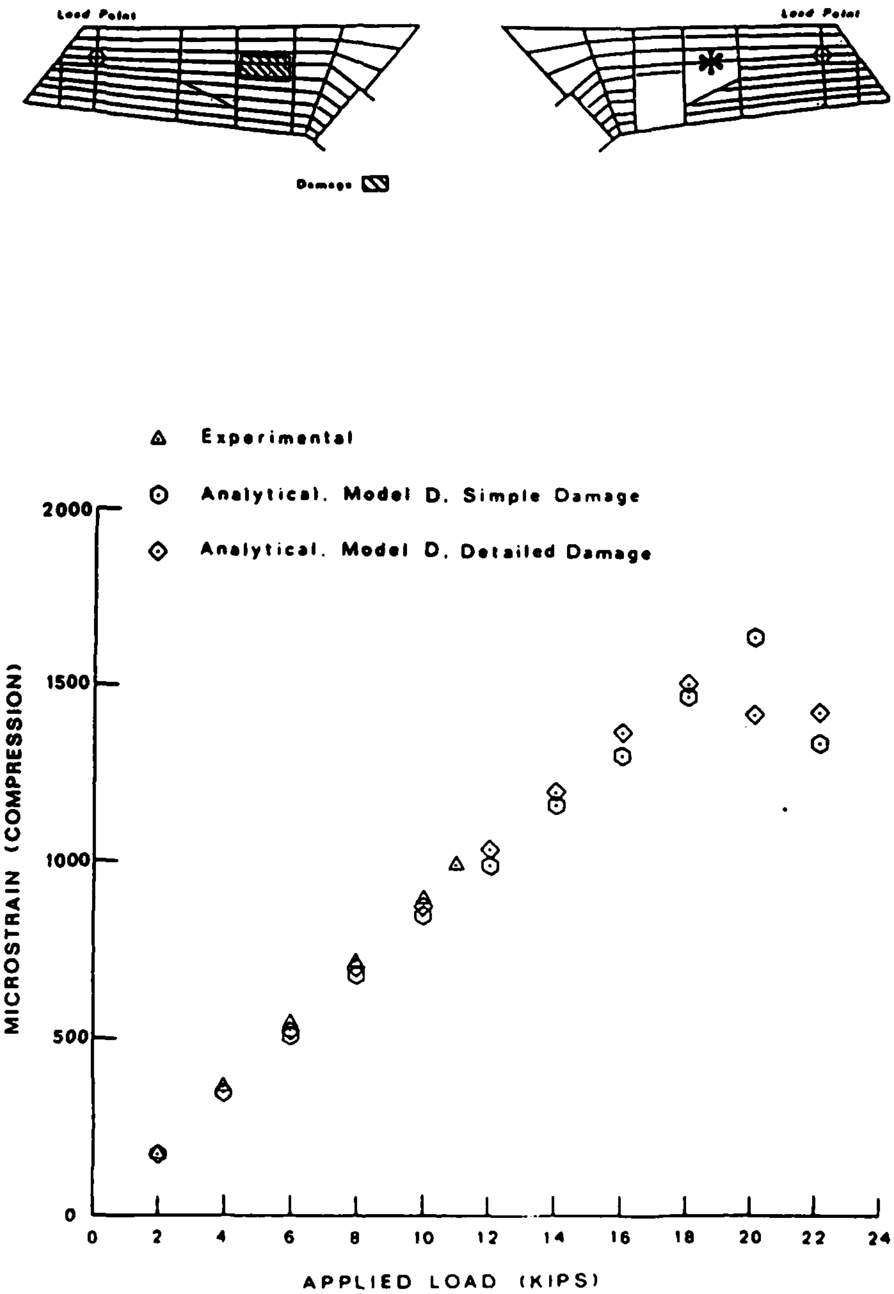
(f) Test 3B, Rear Spar

Figure 26. (Continued)



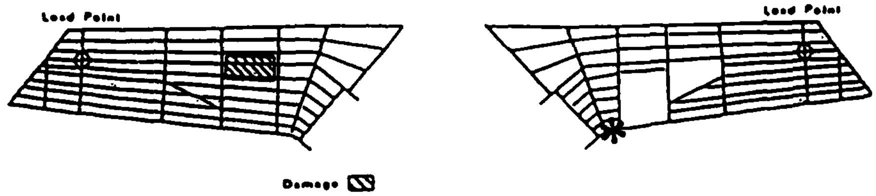
(a) Rod Element 458

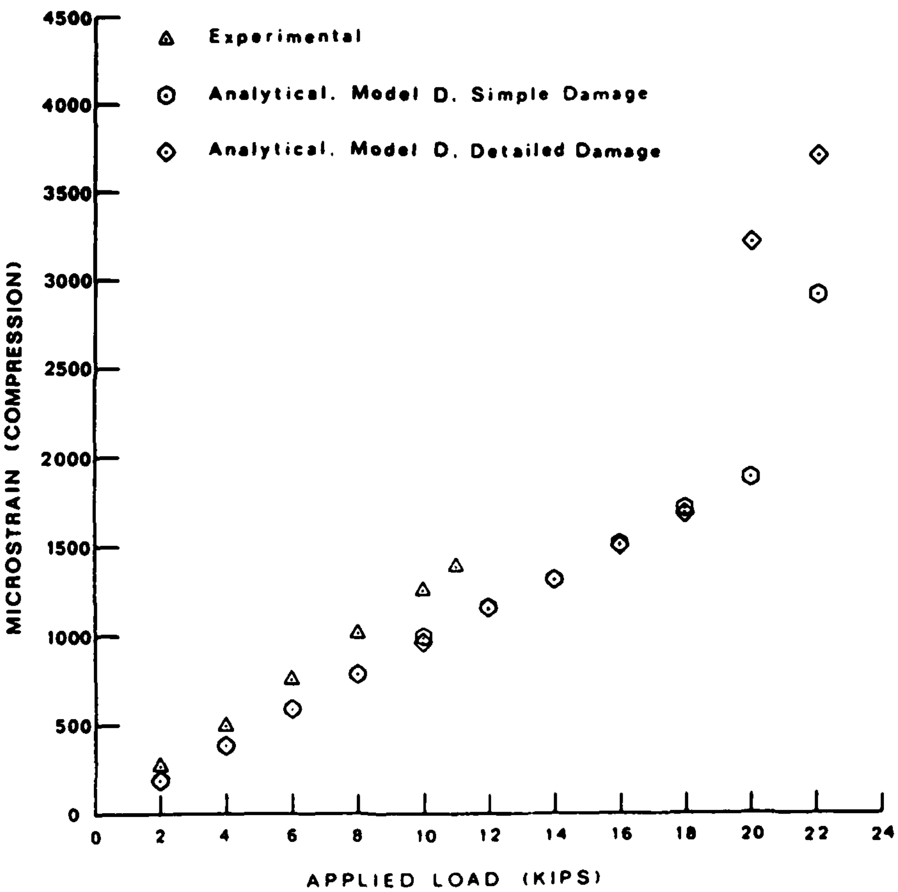
Figure 27. Comparison of Strains for Test 1



(b) Rod Element 476

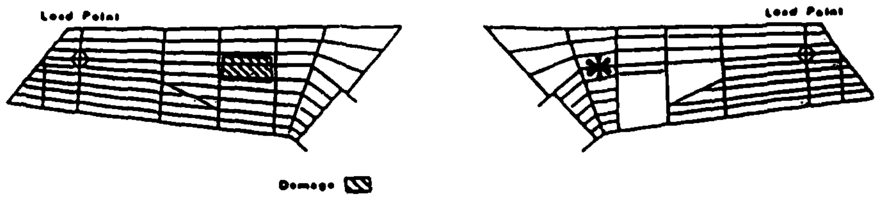
Figure 27. (Continued)

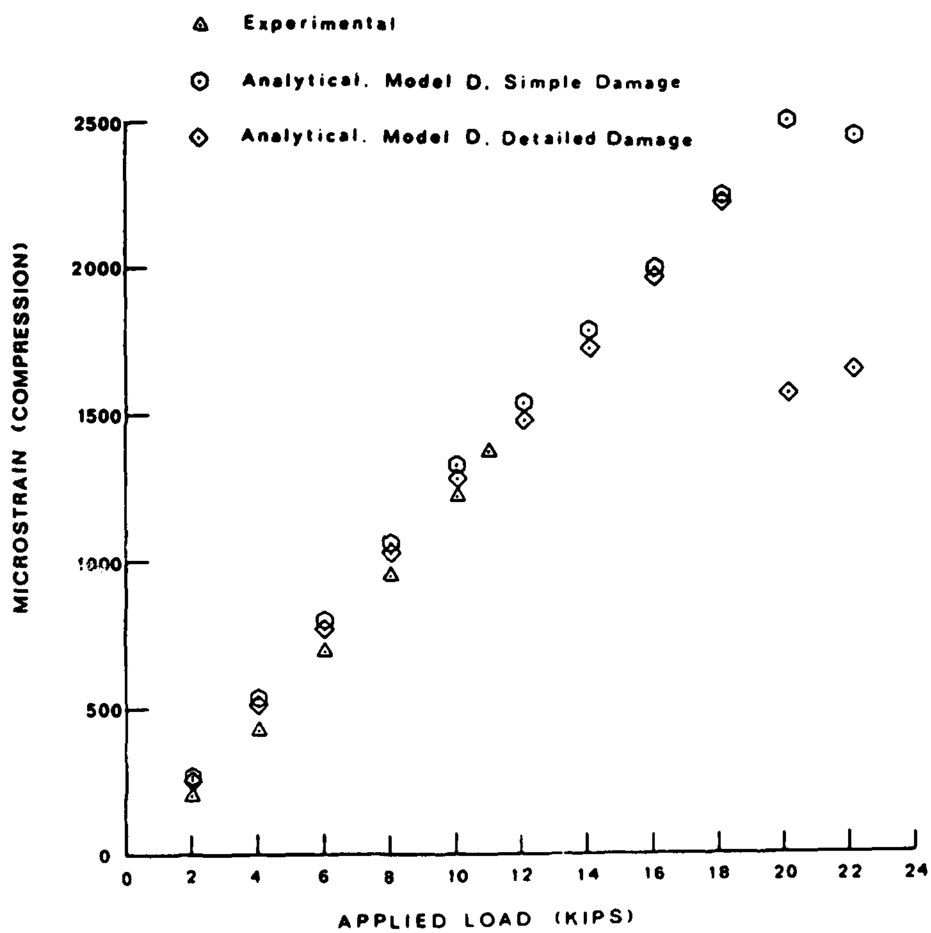




(c) Rod Element 564

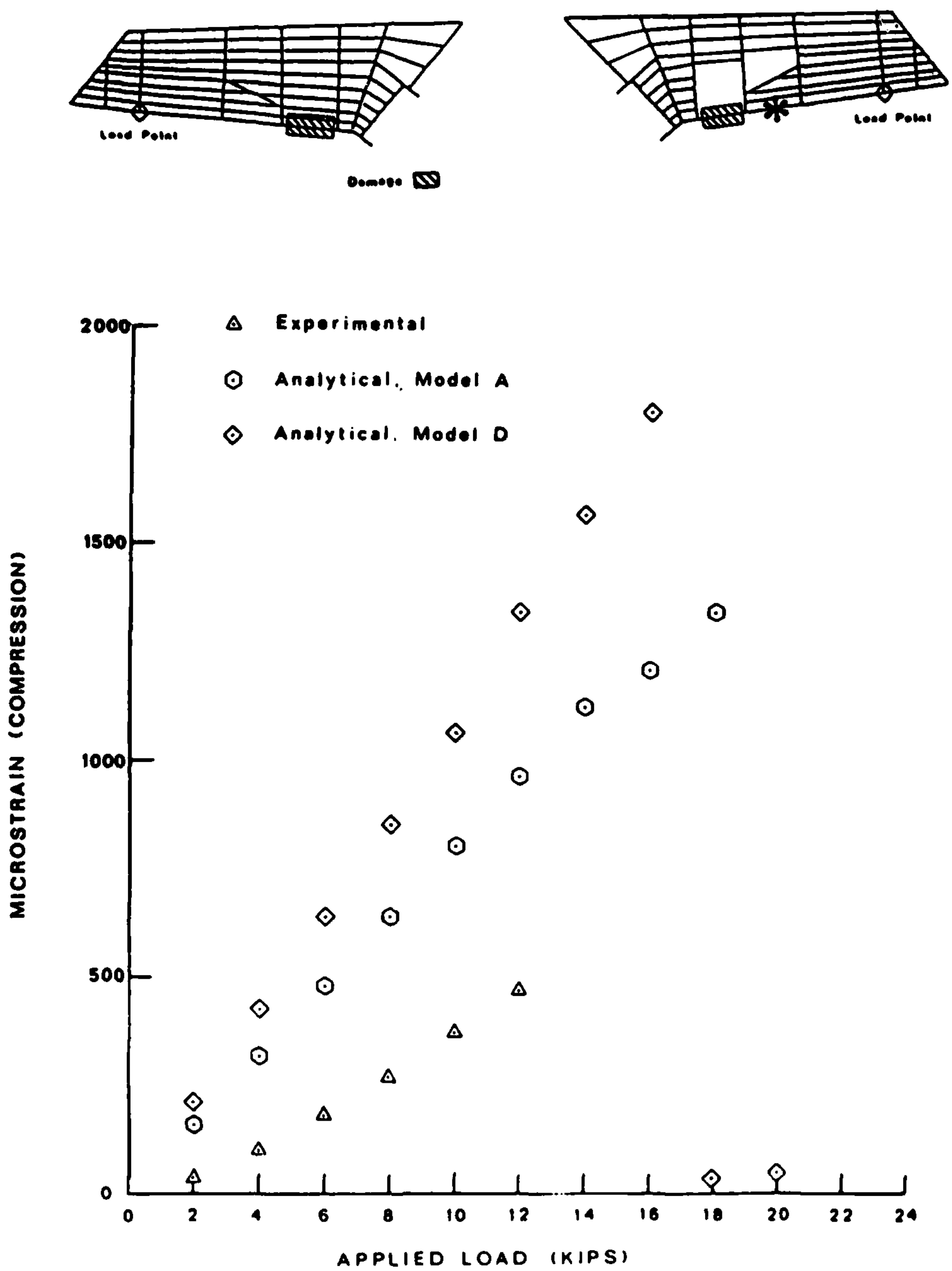
Figure 27. (Continued)





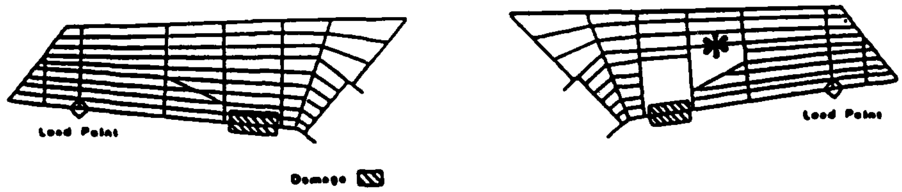
(d) Rod Element 576

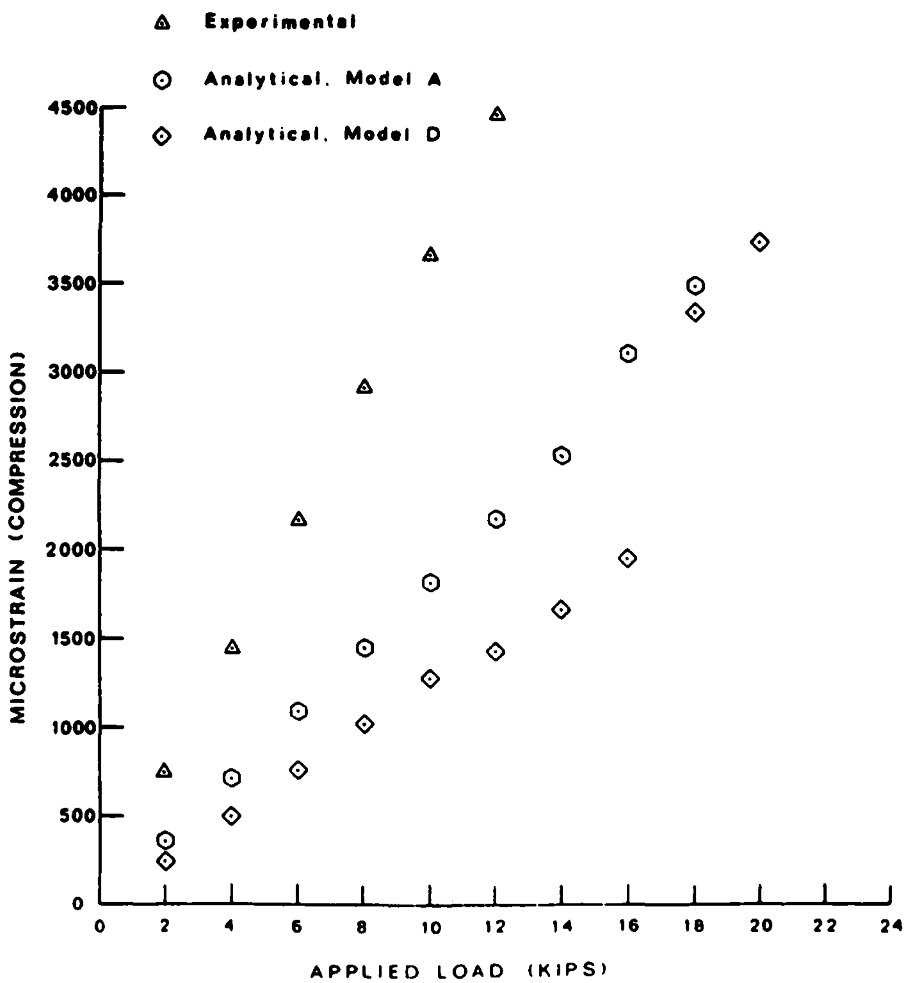
Figure 27. (Continued)



(a) Rod Element 458

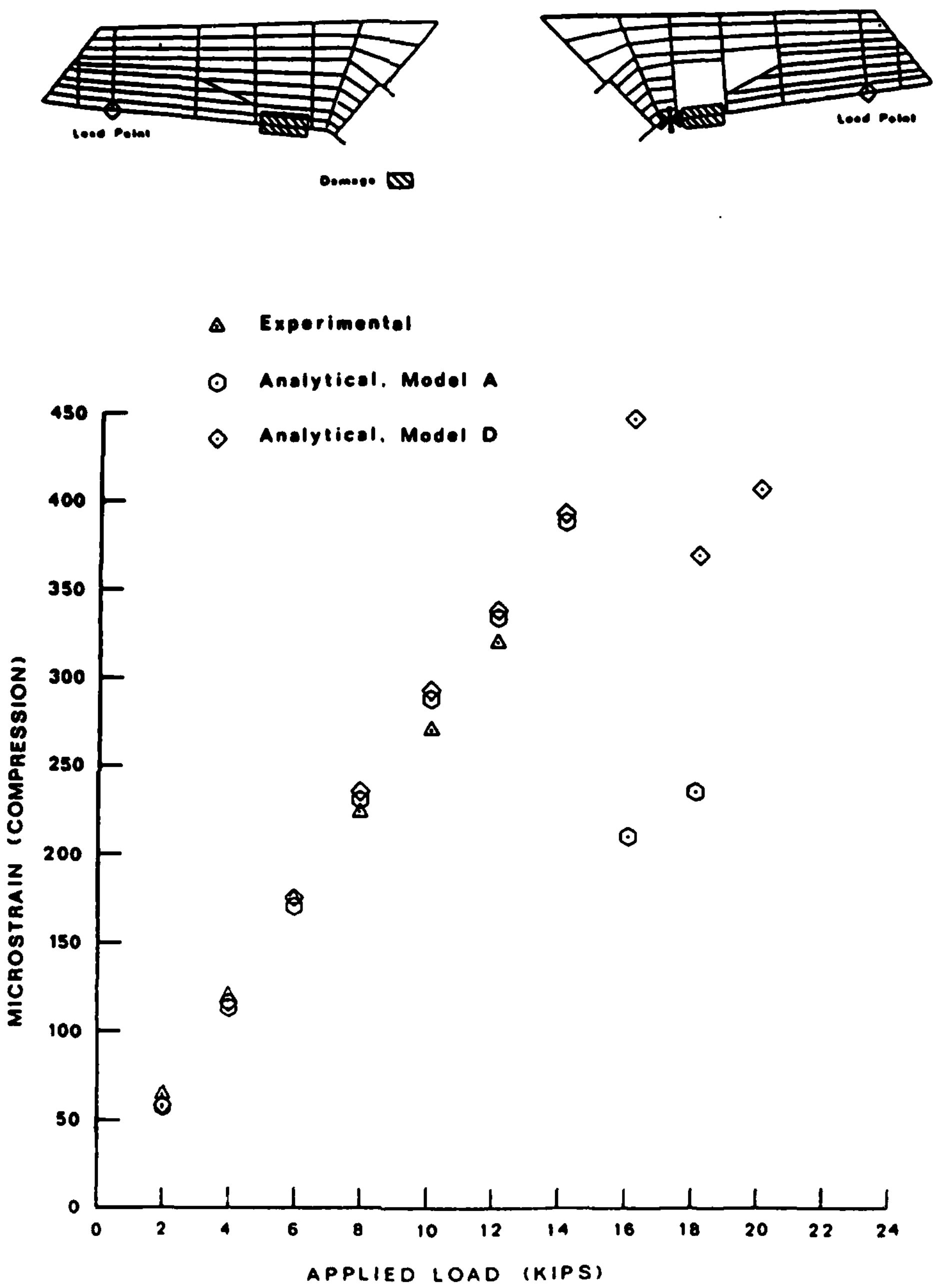
Figure 28. Comparison of Strains for Test 2C





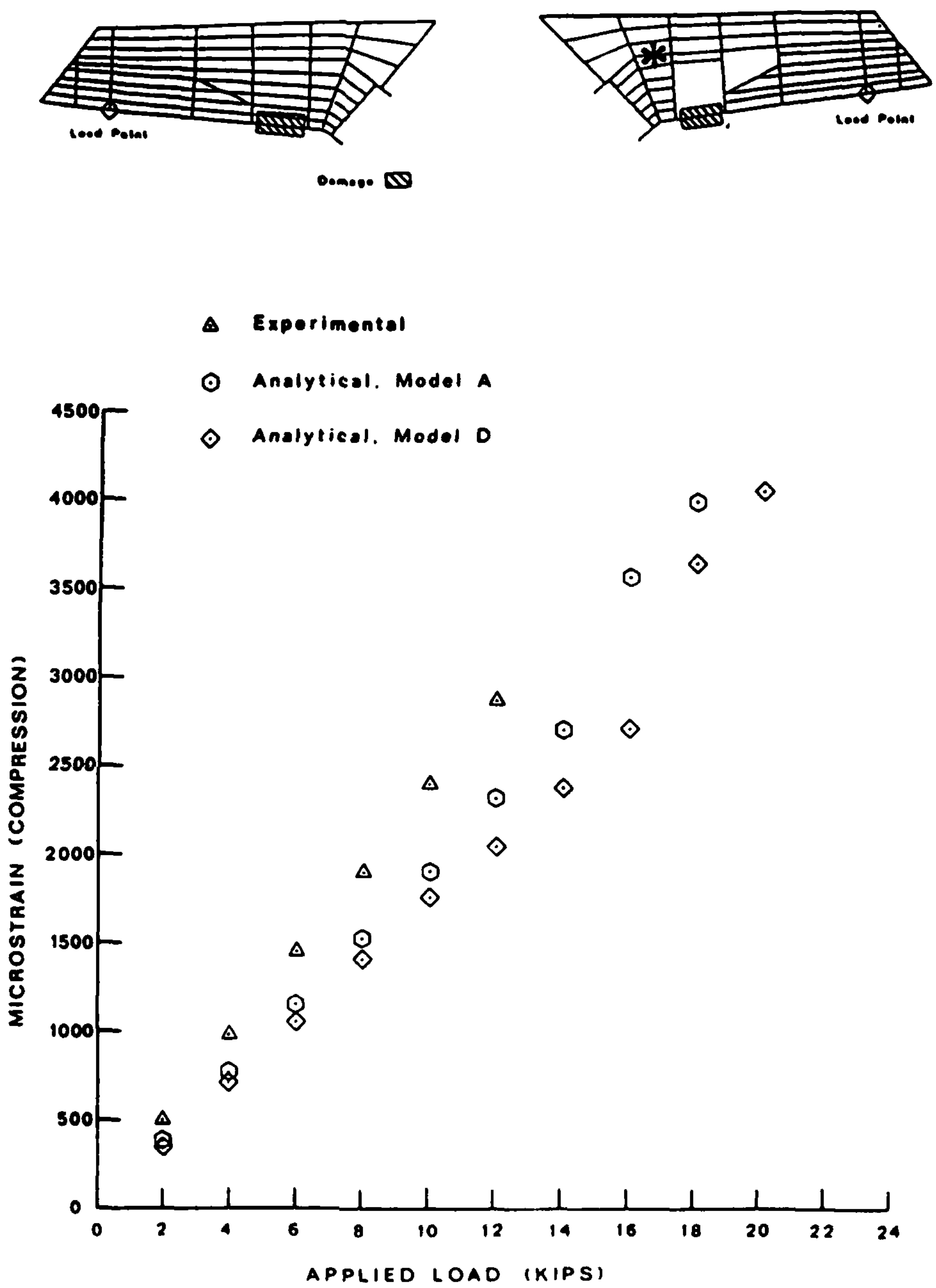
(b) Rod Element 476

Figure 28. (Continued)



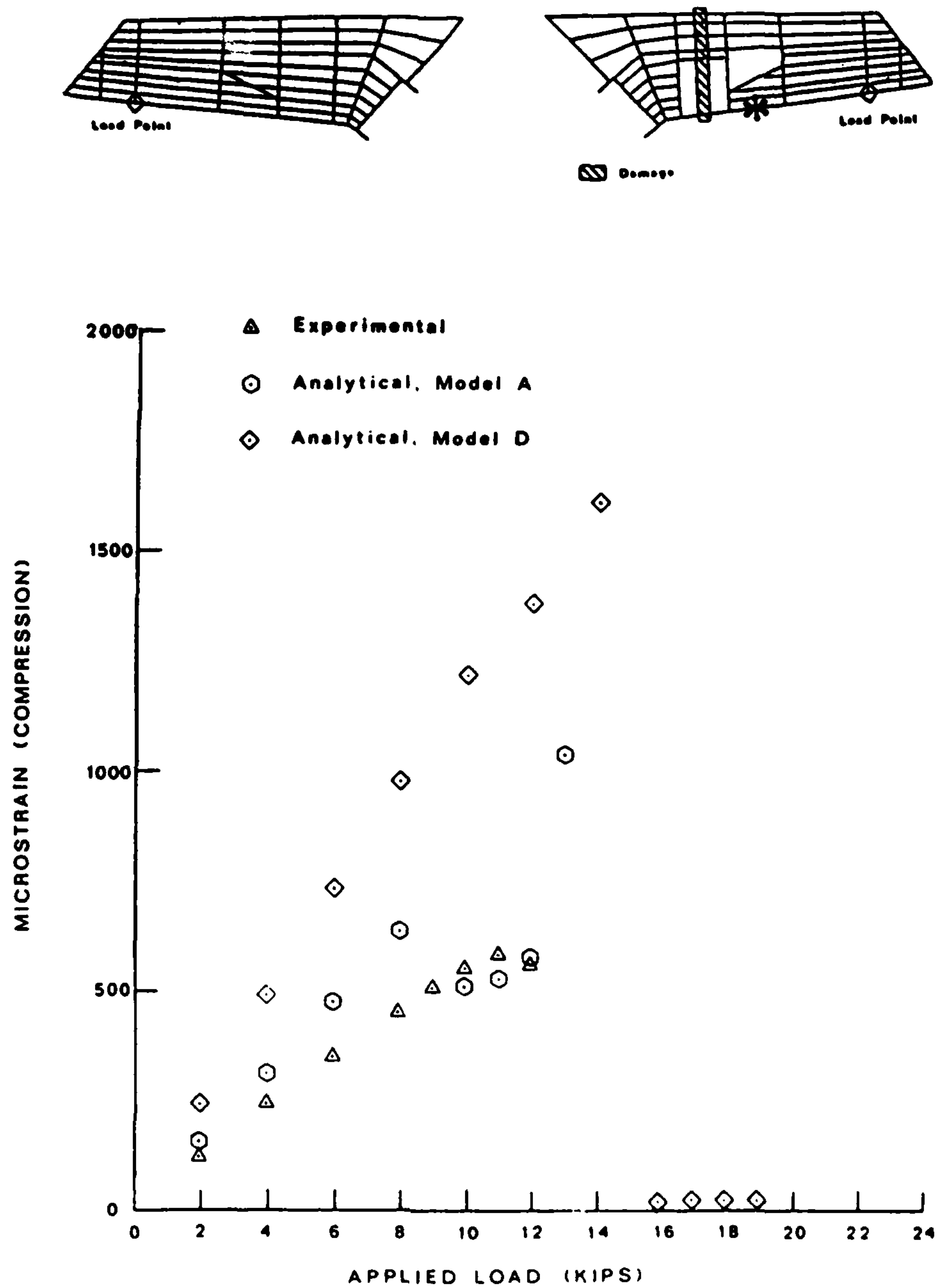
(c) Rod Element 564

Figure 28. (Continued)



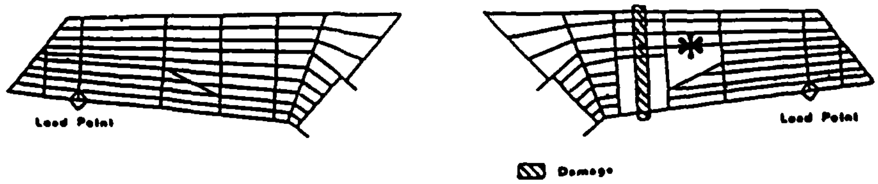
(d) Rod Element 576

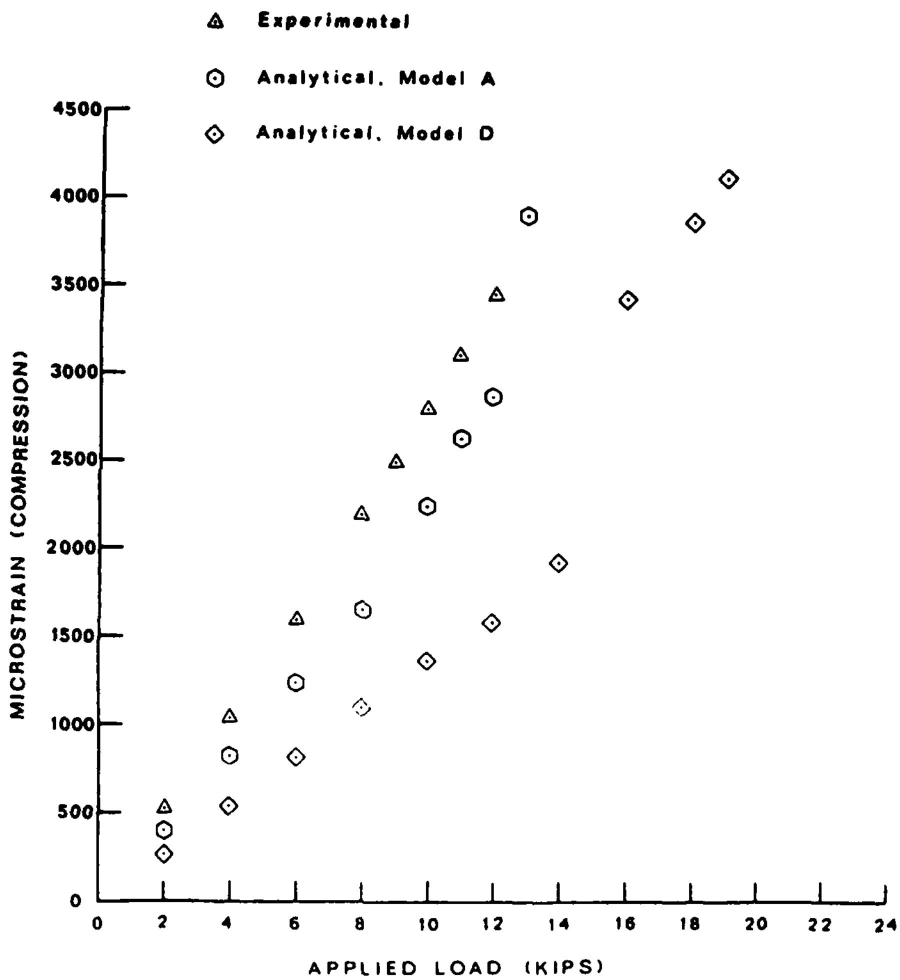
Figure 28. (Continued)



(a) Rod Element 458

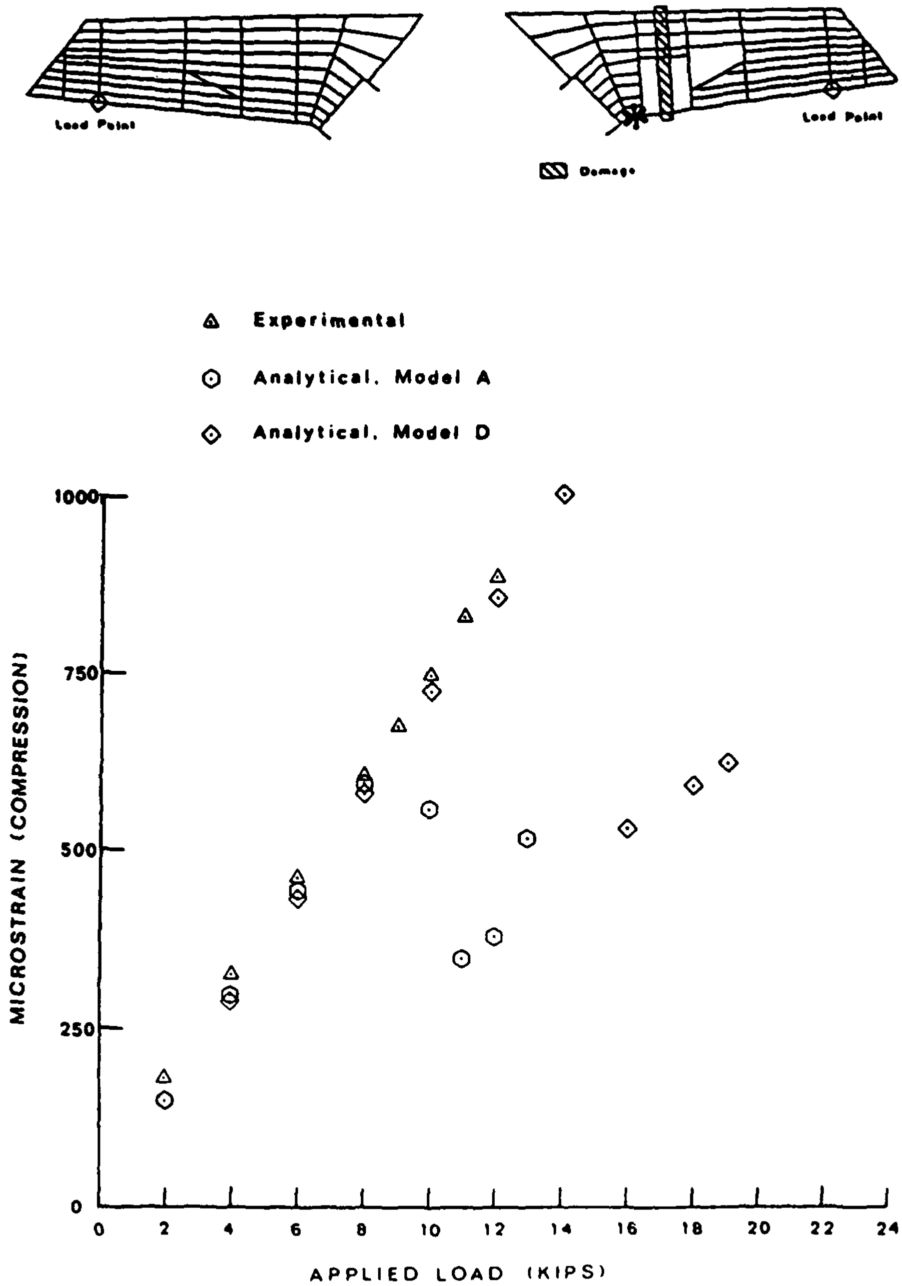
Figure 29. Comparison of Strains for Test 3B





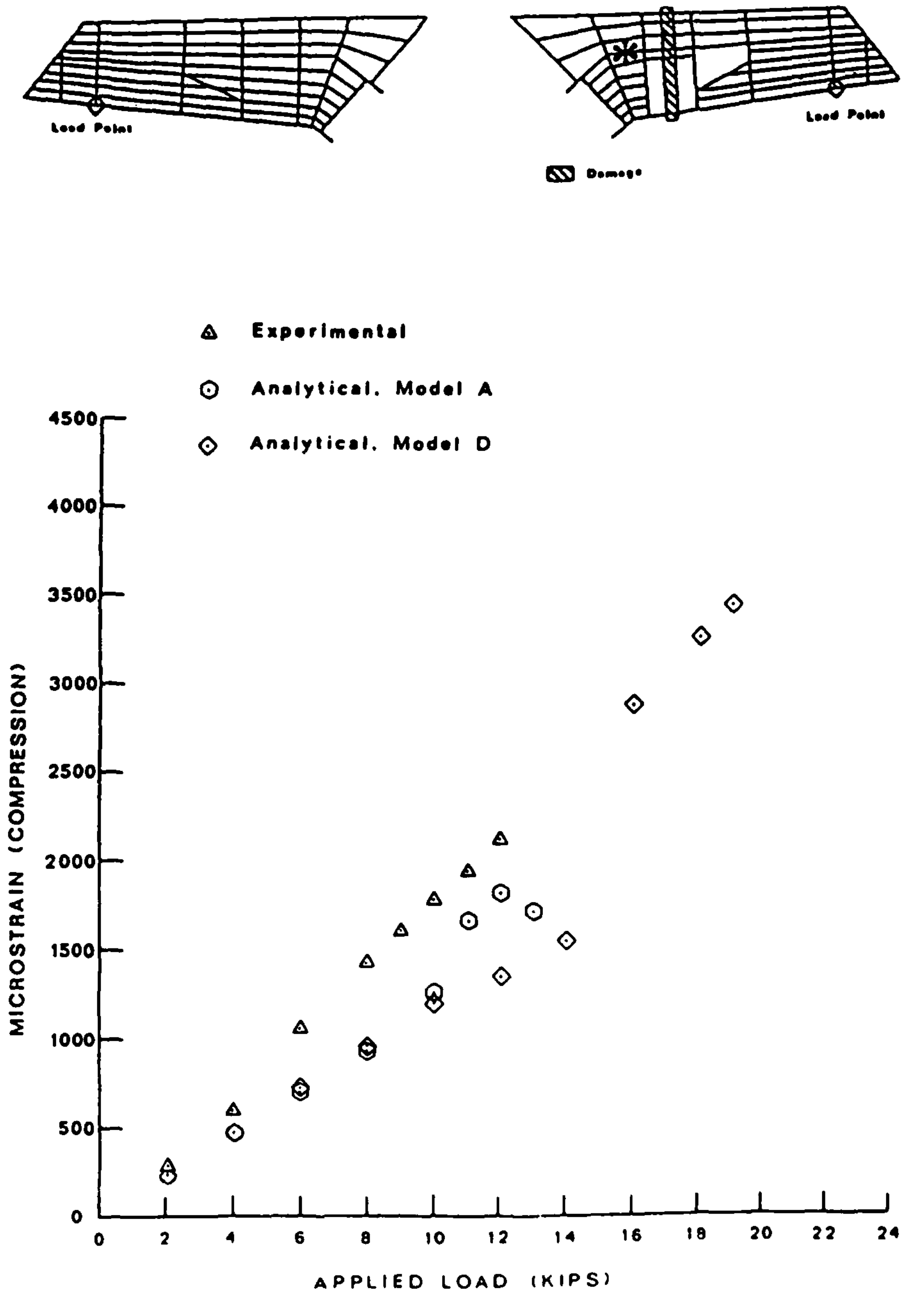
(b) Rod Element 476

Figure 29. (Continued)



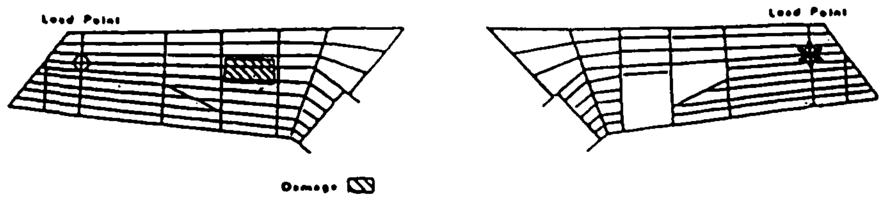
(c) Rod Element 564

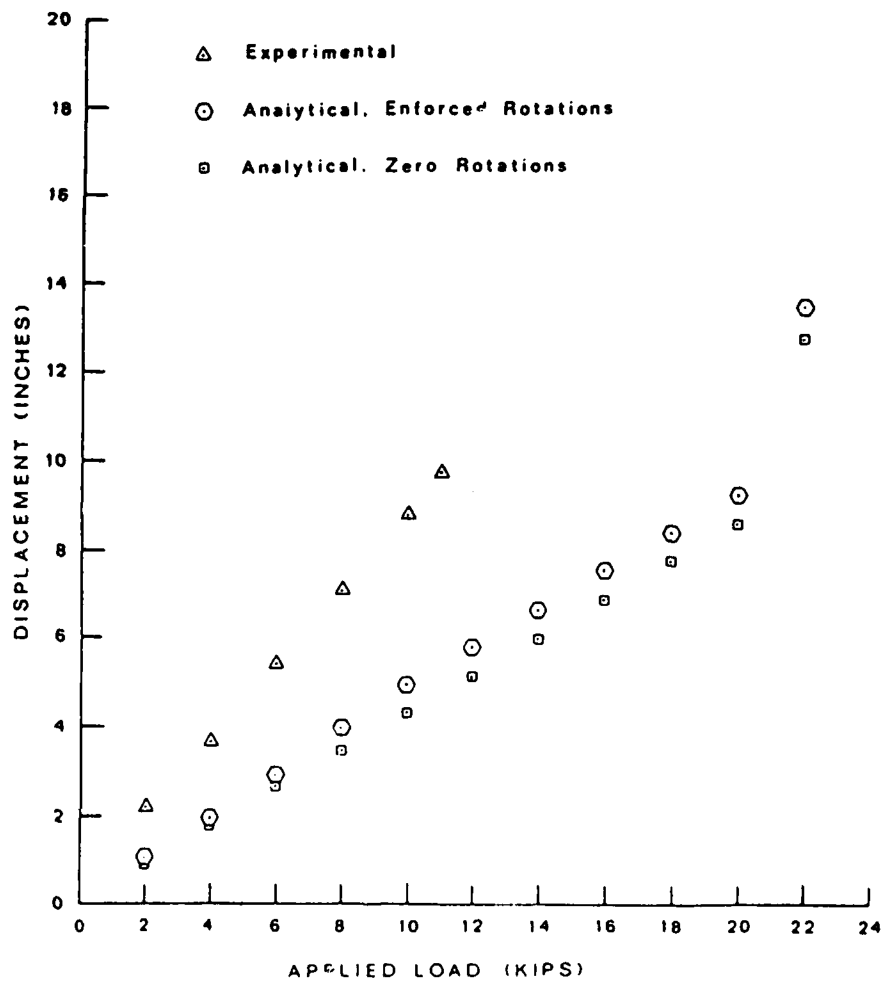
Figure 29. (Continued)



(d) Rod Element 576

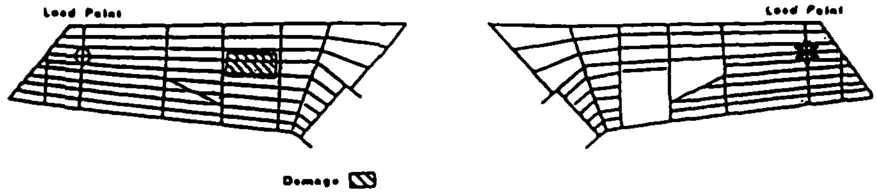
Figure 29. (Continued)

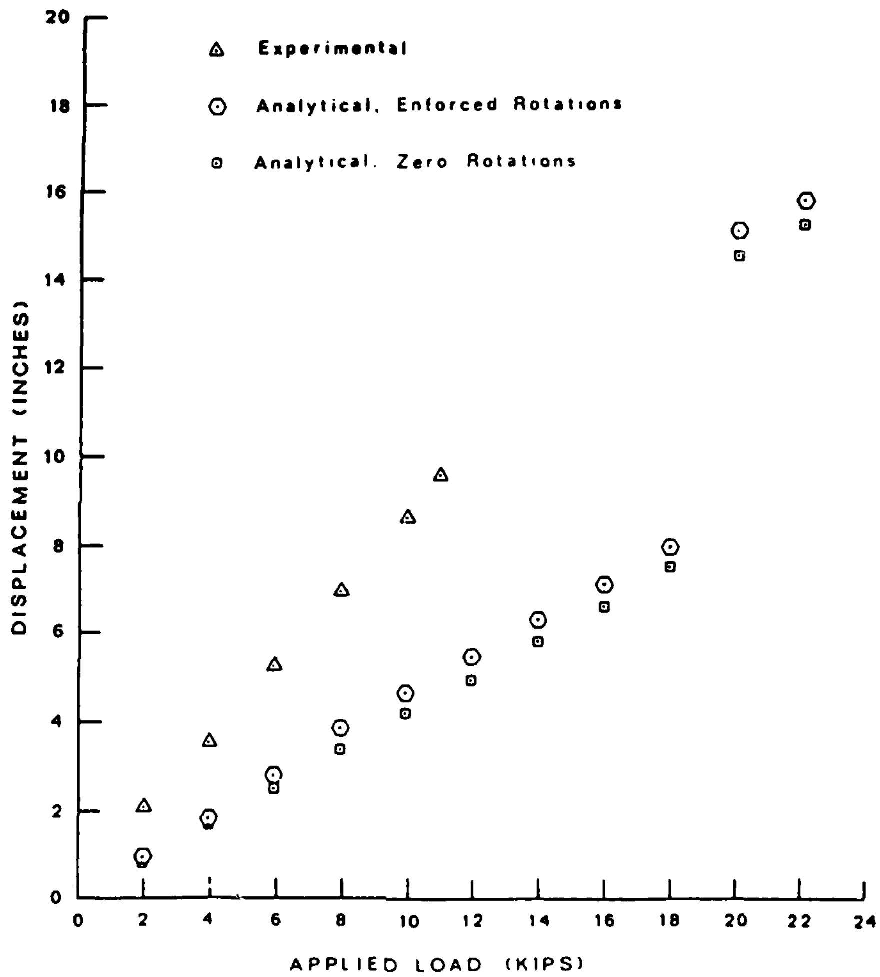




(a) Test 1, Model D (with torsional stiffness rods), Simple

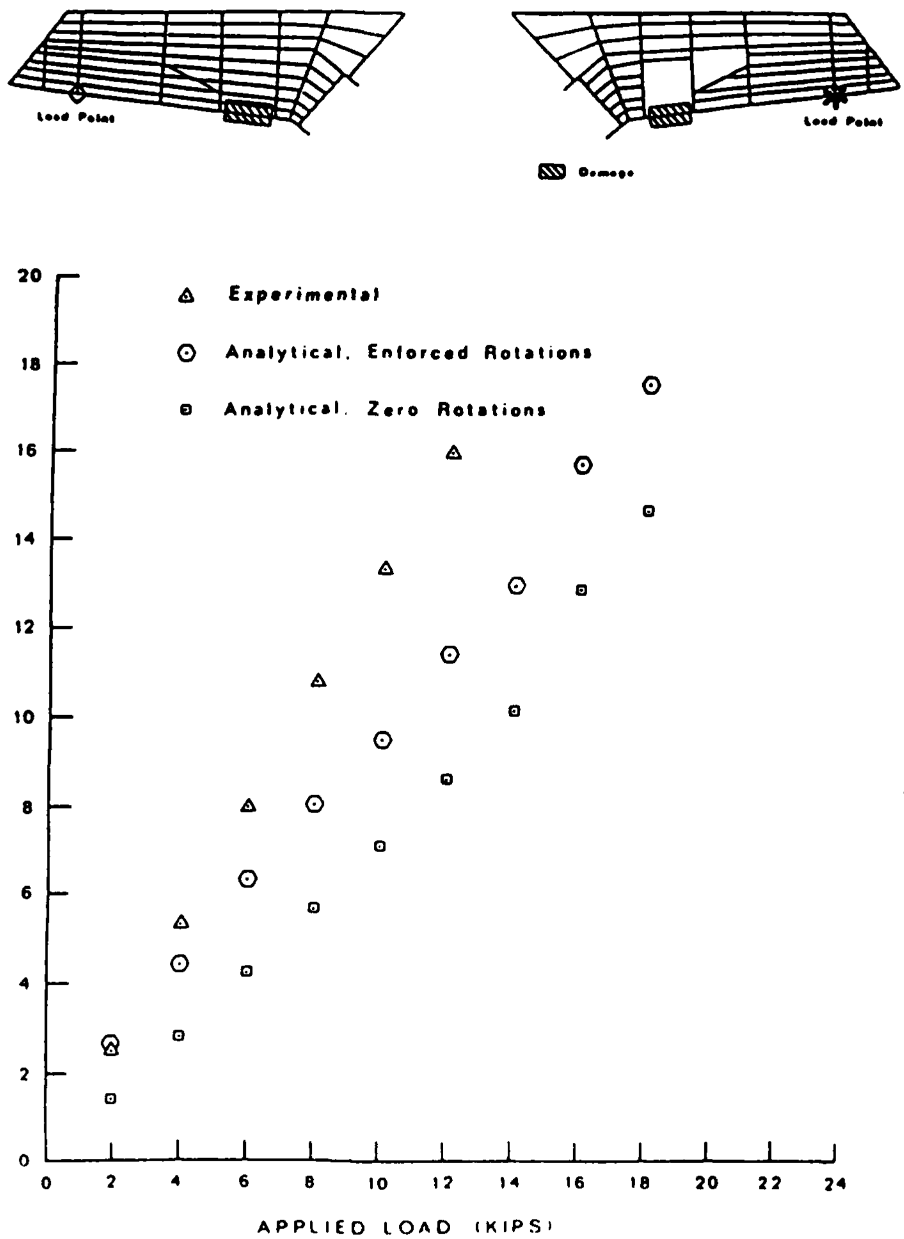
Figure 30. Load Point Displacements for Test 1





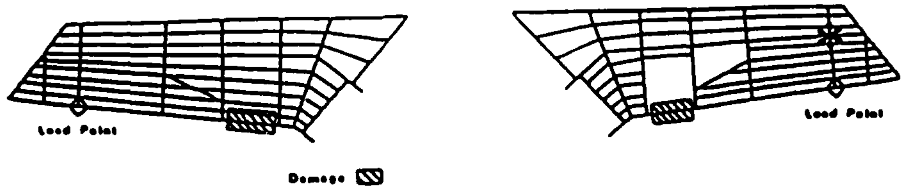
(b) Test 1, Model D (with torsional stiffness rods), Detailed

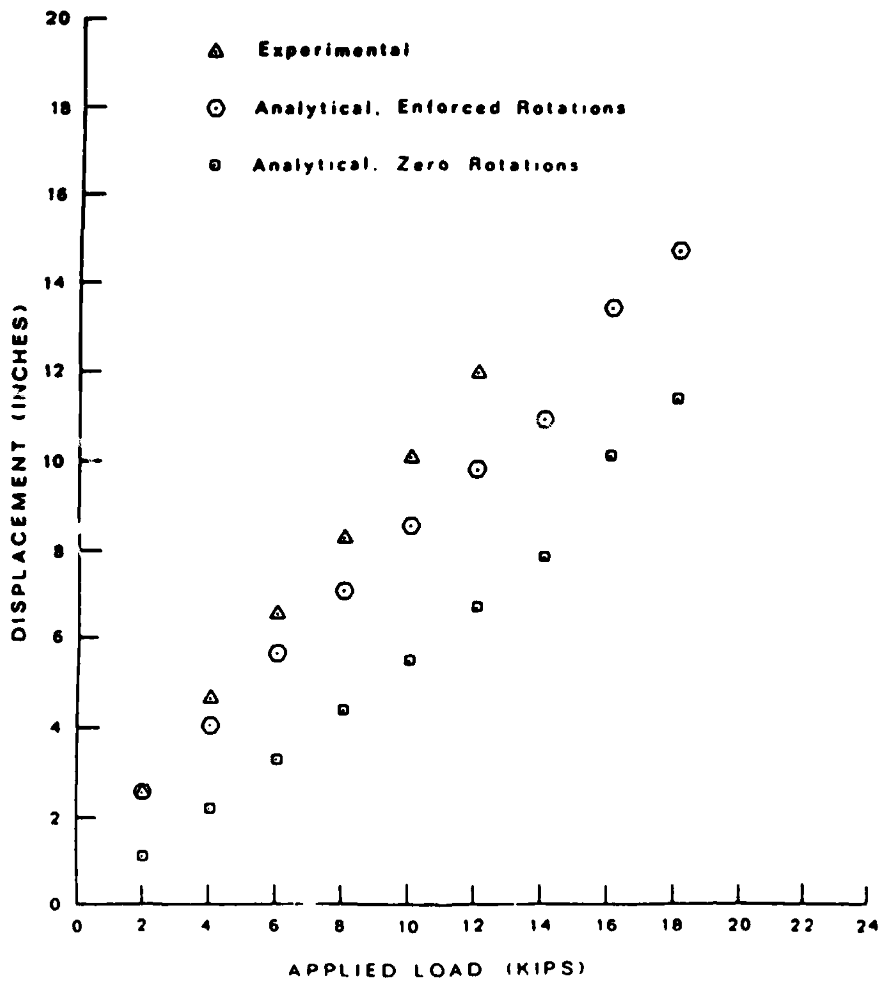
Figure 30. (Continued)



(a) Load Point, Model A (without torsional stiffness rods)

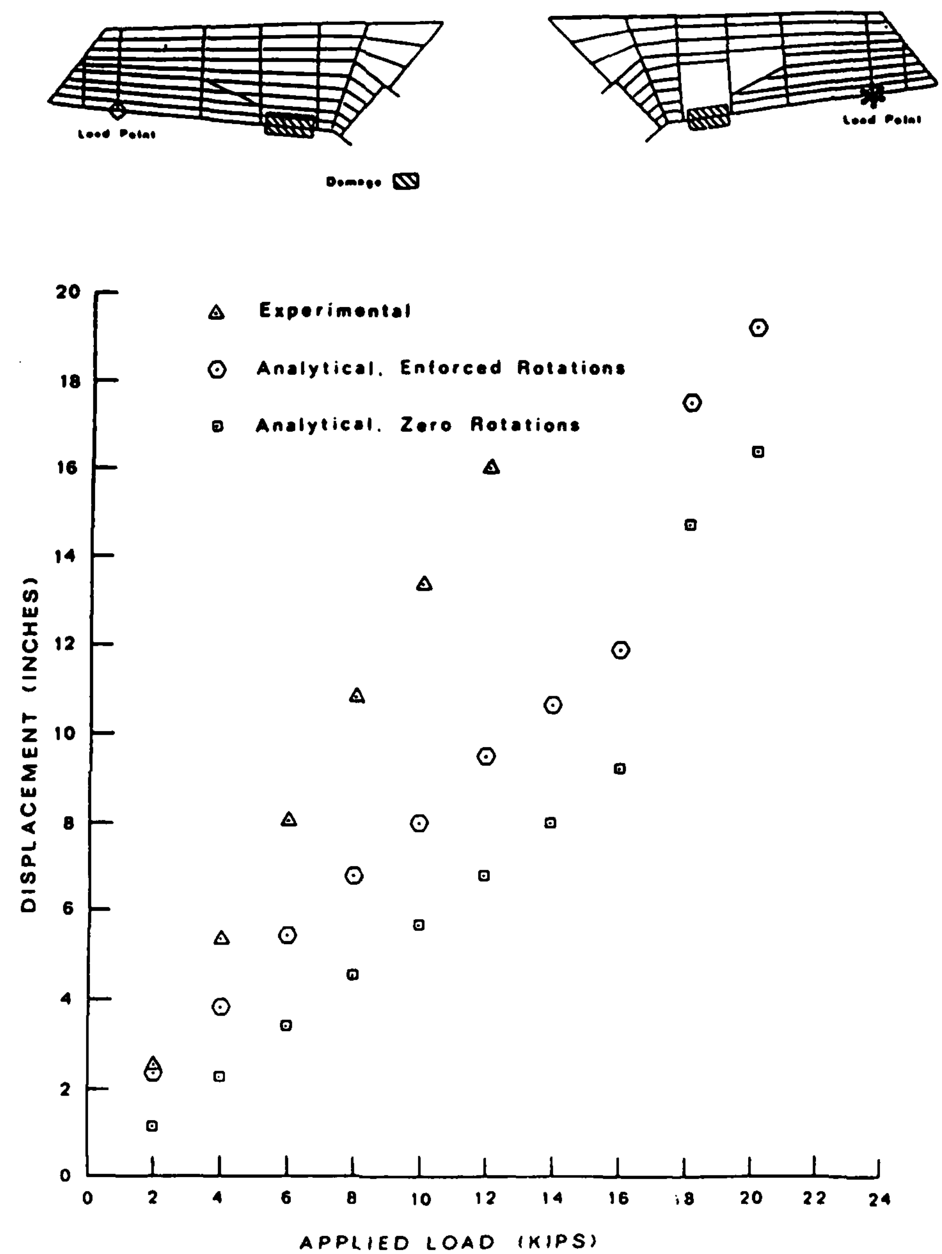
Figure 31. Single-Point Displacements for Test 2C





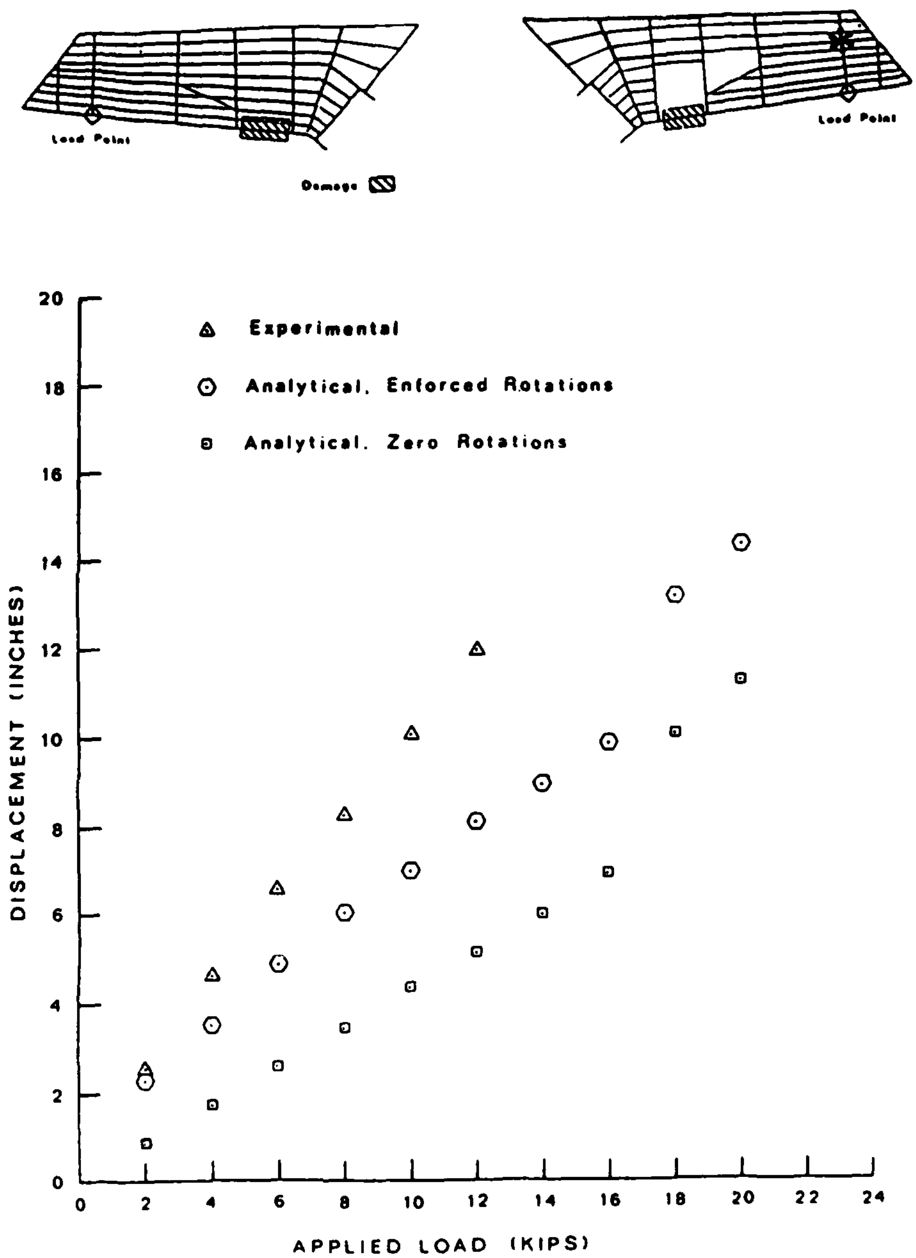
(b) Node 46. Model A (without torsional stiffness rods)

Figure 31. (Continued)



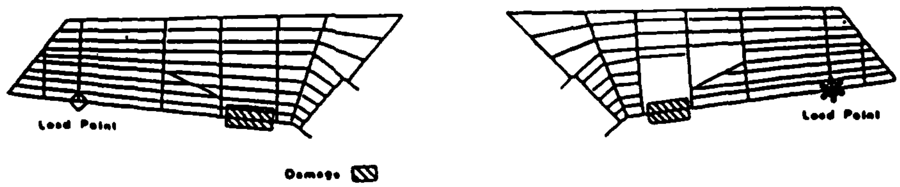
(c) Load Poin., Model C (without torsional stiffness rods)

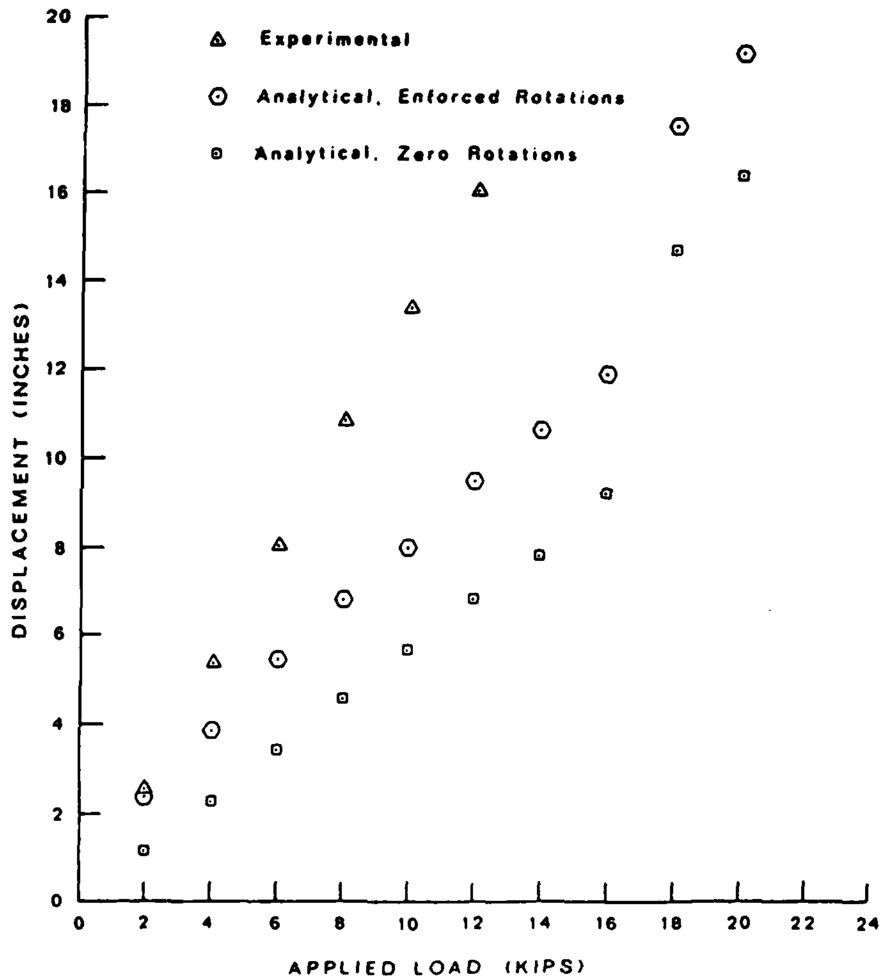
Figure 31. (Continued)



(d) Node 46, Model C (without torsional stiffness rods)

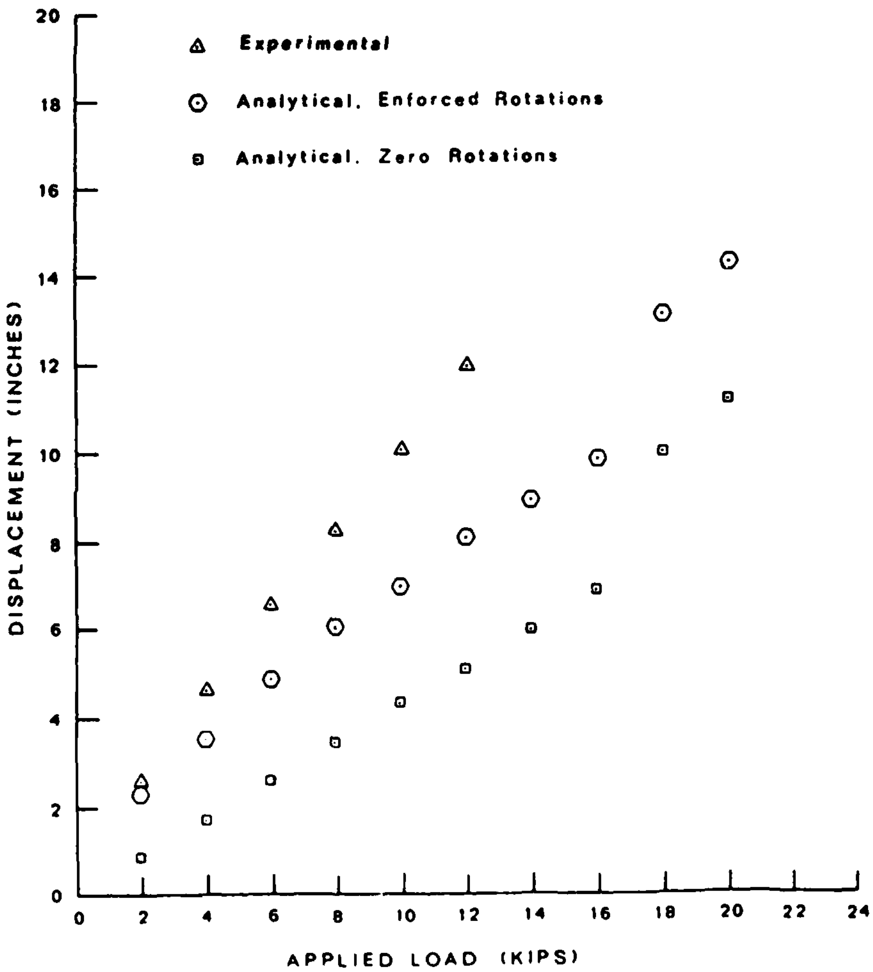
Figure 31. (Continued)





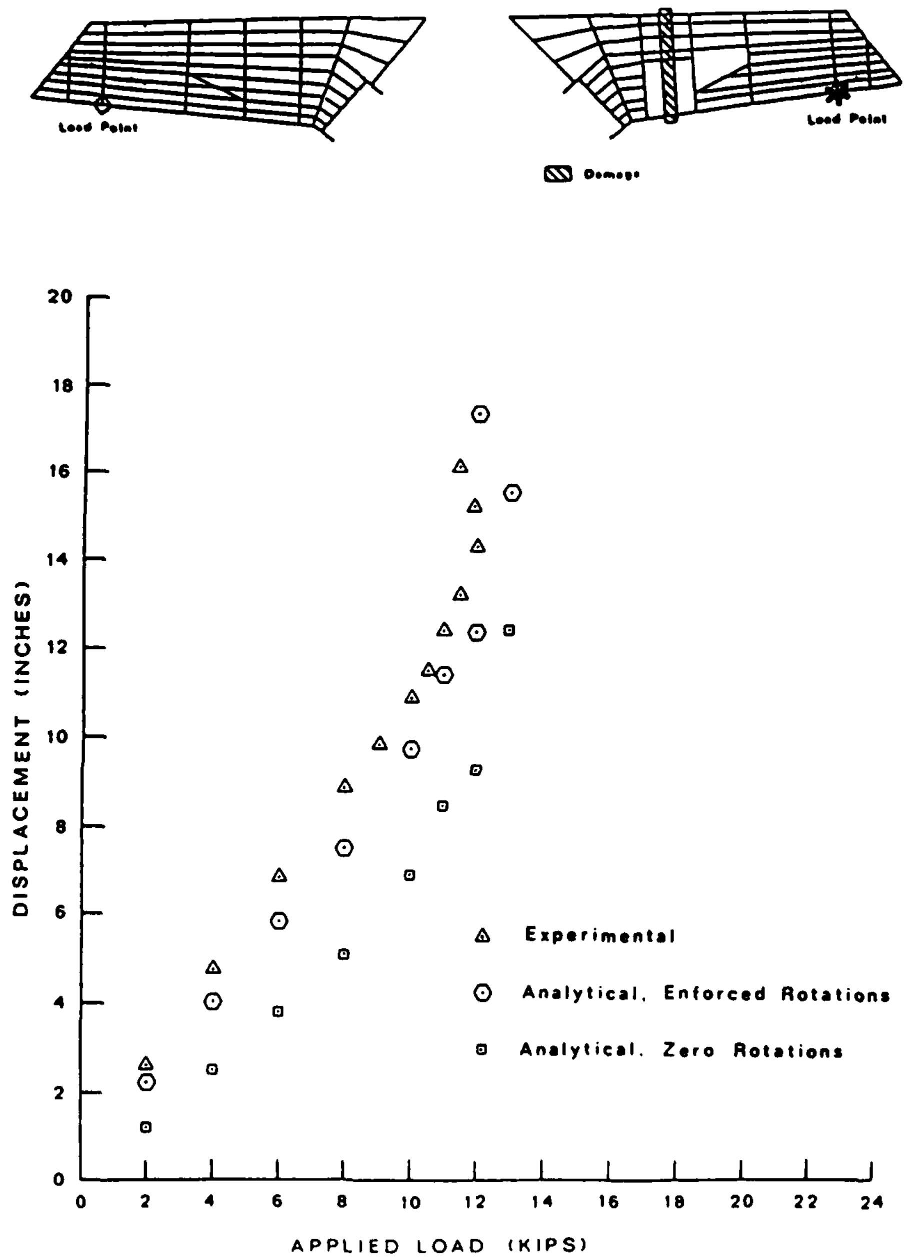
(e) Load Point, Model D (with torsional stiffness rods)

Figure 31. (Continued)



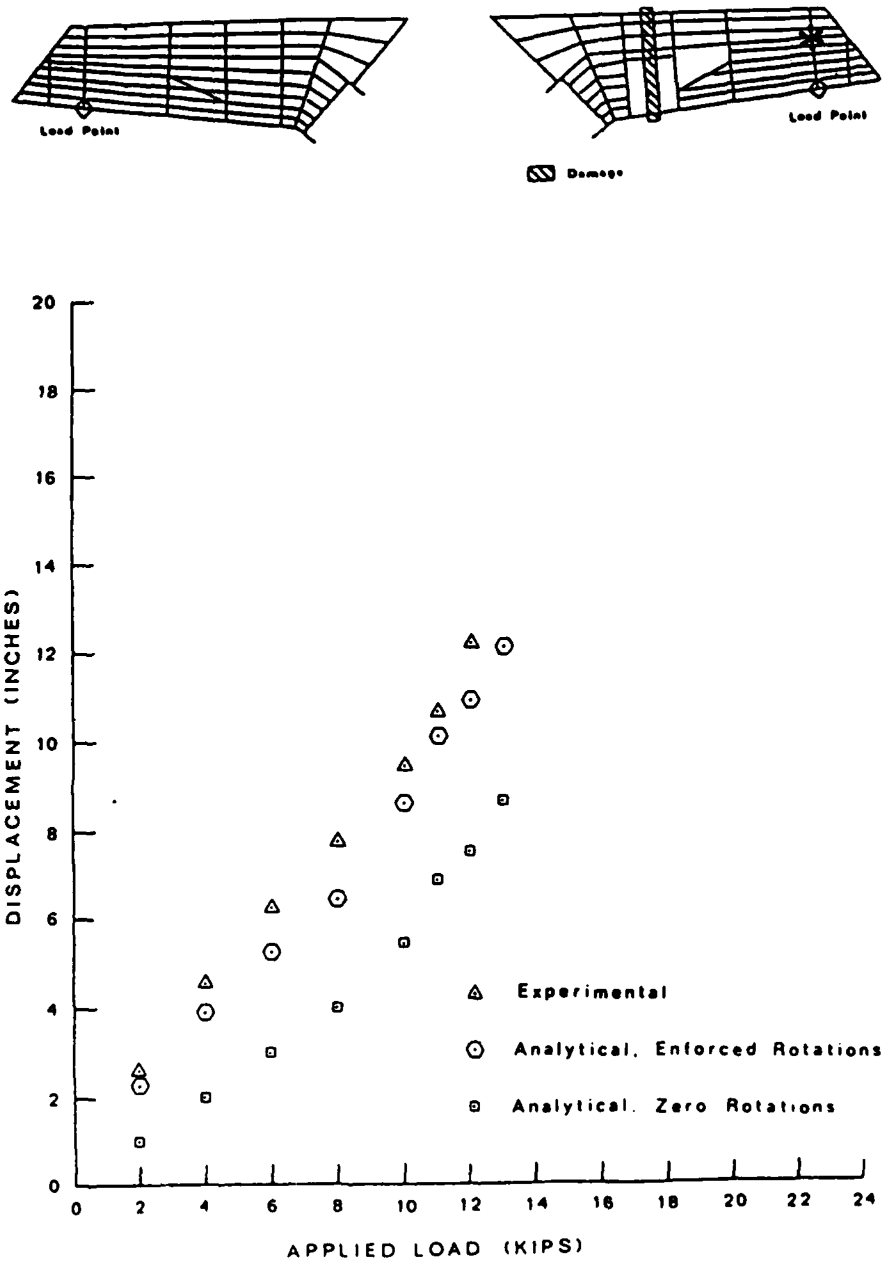
(f) Node 46, Model D (with torsional stiffness rods)

Figure 31. (Continued)



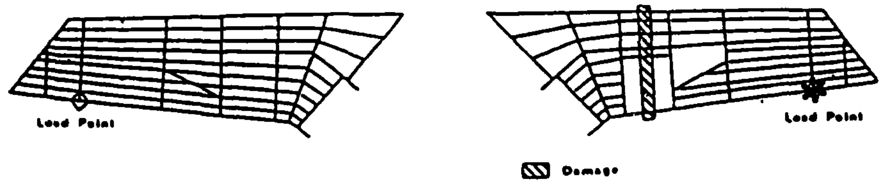
(a) Load Point, Model A (without torsional stiffness rods)

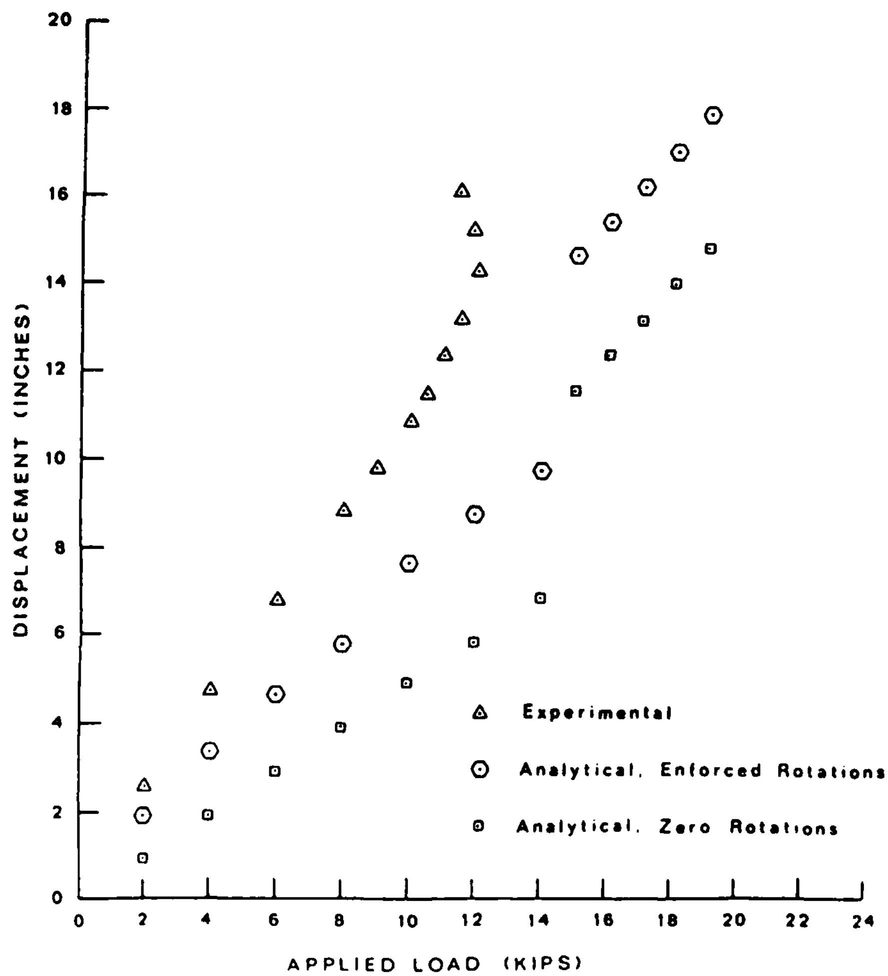
Figure 32. Single-Point Displacements for Test 3B



(b) Node 46. Model A (without torsional stiffness rods)

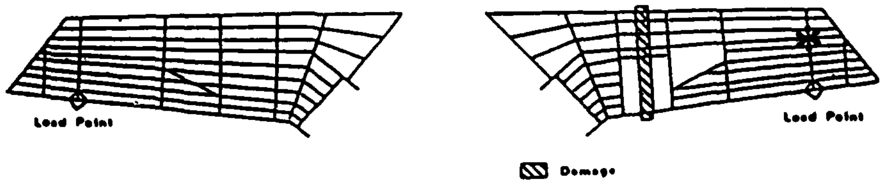
Figure 32. (Continued)

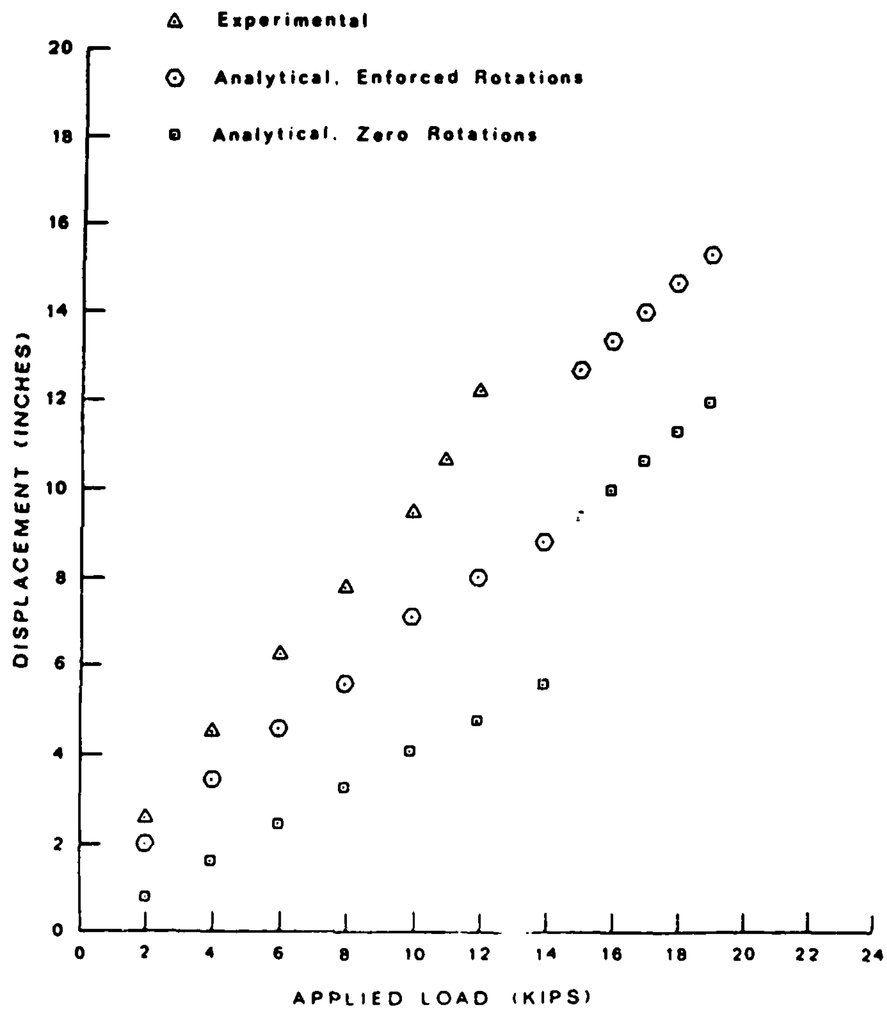




(c) Load Point, Model C (without torsional stiffness rods)

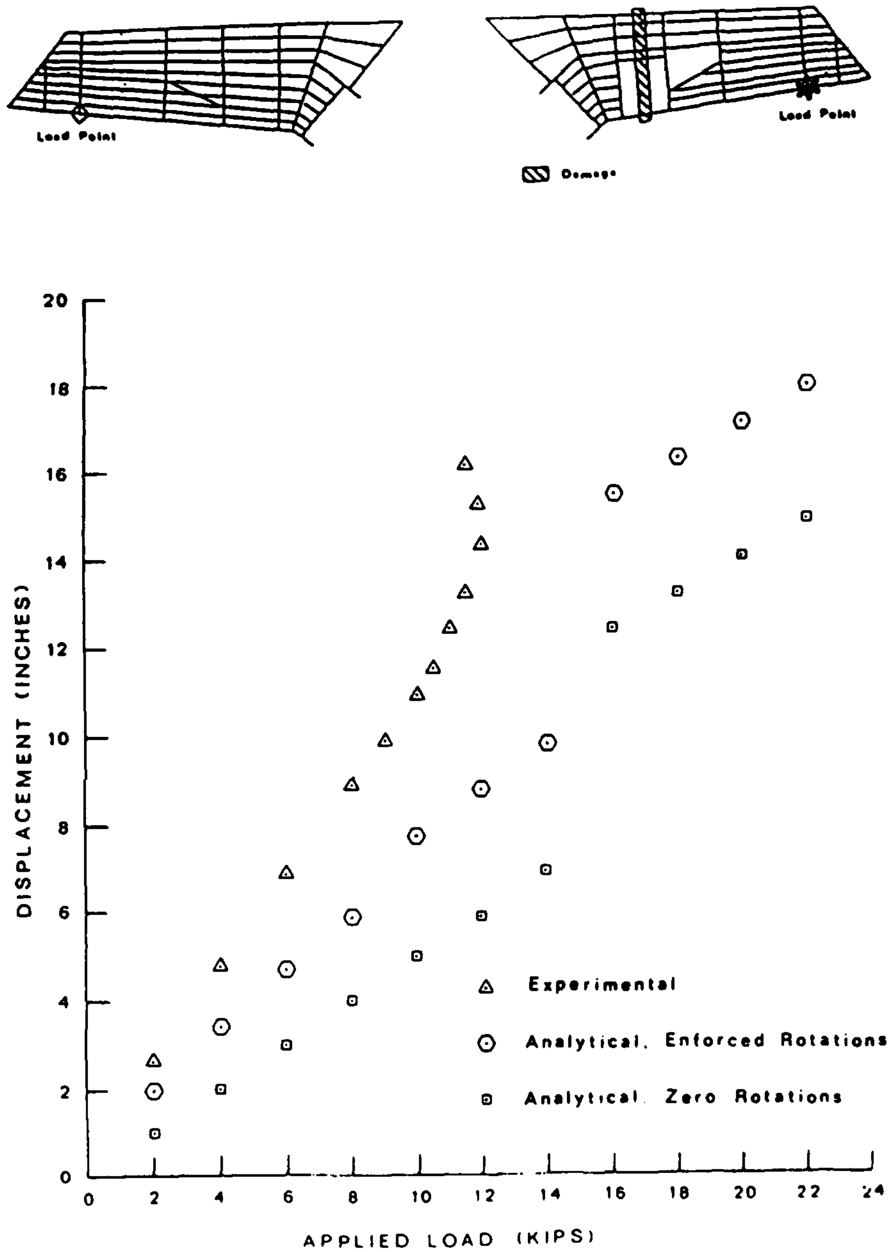
Figure 32. (Continued)





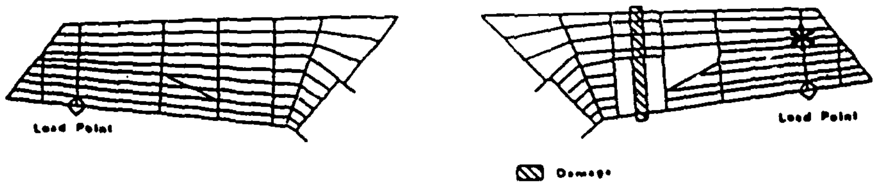
(d) Node 46, Model C (without torsional stiffness rods)

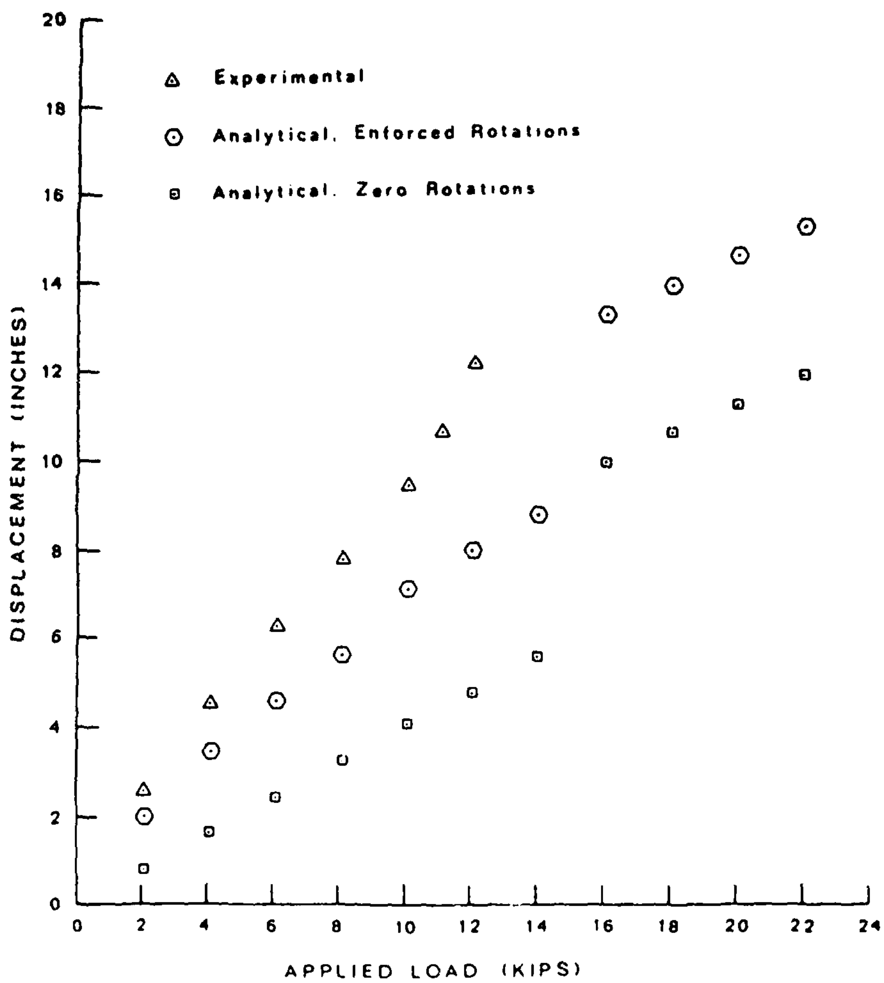
Figure 32. (Continued)



(e) Load Point, Model D (with torsional stiffness rods)

Figure 32. (Continued)





(f) Node 46, Model D (with torsional stiffness rods)

Figure 32. (Continued)

AD-A125 266 ANALYSIS OF PROGRESSIVE COLLAPSE OF COMPLEX STRUCTURES 3/3
(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH
G E RIGGS DEC 82 AFIT/CI/NR-82-63D
UNCLASSIFIED F/G 12/1 NL

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX J

SUMMARY OF ANALYTICAL RESULTS

TABLE V

SUMMARY OF RESULTS FOR TEST 1,
MODEL D, SIMPLE DAMAGE

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
1	10	68 118	---	---
2	12	56 112	---	---
3	14	136	---	---
4	16	54 80 106 124 135 255	529	529
5	14	---	---	---
6	16	---	---	---
7	18	82	---	---
8	20	111 117 132 134 258	---	---
9	22	64 116	117	117
10	20	---	137 573	573
11	18	---	119	119
12	16	---	135 571	135
13	14	---	531	531
14	12	---	---	---
15	14	---	---	---
16	16	105 257	---	---
17	18	85	105 121	105
18	16	123	533	533
19	14	---	---	---
20	16	---	123	123
21	14	---	---	---
22	16	---	---	---
23	18	---	579	579
24	16	---	---	---
25	18	---	---	---
26	20	---	---	---
27	22	52 62 89 107 125	75 248	248
28	20	93 114 143 256	107 125 213 257	125

TABLE V (Continued)

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
29	18	126	107 256 257 581	257
30	16	---	581	581
31	14	---	126	126
32	12	---	582	582
33	10	---	---	---
34	12	---	---	---
35	14	---	---	---

TABLE VI

SUMMARY OF RESULTS FOR TEST 1, MODEL D, DETAILED DAMAGE

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
1	10	68 118	---	---
2	12	56 112 136	---	---
3	14	---	---	---
4	16	80 135	---	---
5	18	54 106 124 132	---	---
6	20	116 117 134 254 255 258	121	121
7	18	---	117 137	137
8	16	111	119	119
9	14	256 257	577	577
10	12	---	---	---
11	14	123	---	---
12	16	82 105 126	123 531 9529	123 9529
13	14	---	579	579
14	12	---	---	---
15	14	125	---	---
16	16	85 143	105 125	125
17	14	---	257	257
18	12	---	---	---
19	14	---	581	581
20	12	---	---	---
21	14	---	---	---
22	16	114	---	---
23	18	62 64 89	---	---
24	20	52 93	68 256	68 256
25	18	50 130	---	---
26	20	55	---	---
27	22	---	126	126
28	20	---	582	582
29	18	---	---	---

TABLE VI (Continued)

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
30	20	---	---	---
31	22	---	75	75
32	20	67 73	55 57 473	473
33	18	97	57 73	73
34	16	---	55 471	55
35	14	53	427	427

TABLE VII

SUMMARY OF RESULTS FOR TEST 2C,
MODEL A, SIMPLE DAMAGE

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
1	10	111 135	---	---
2	12	80	---	---
3	14	49 81 82 133 136 255	---	---
4	16	68 129 134	109	109
5	14	114 131	127	127
6	12	132	---	---
7	14	130	---	---
8	16	56	---	---
9	18	50 79 107 108	137	137
10	16	---	119 575	575
11	14	113 123 125 143 144	119 129 133 135 139 573 577 579	119 129 579
12	12	142	103 121 131 133 135 139 531 567 577 581 605 615	131 577 581
13	10	85 93 97 105 112 115 116 117 118 124 126 141 254 256 257	113 121 125 133 135 139 140 213 223 224 225 226 227 228 535 536 567 569 573 580 582 589 591 607 611 620 625	133 582
14	8	106	97 108 115 117 121 123 125 126 135 139 140 141 223 224 225 226 227 228 257 528 534 535 536 569 571 573 578 580 589 591 609 611 625 627 629 631 632	135 528
15	6	73	97 104 108 110 113 115 117 121 123 125 126 128 139 140 141 144 212 213 223 224 225 226 227 228 257 530 534 535 536 569 578 580 591 593 601	580

TABLE VII (Continued)

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
15 (Cont.)			618 625 627 628 629 630 631 632	
16	4	---	97 104 111 115 117 118 121 123 124 125 126 128 139 140 141 142 212 213 222 223 224 225 226 227 228 249 257 532 534 535 536 552 555 567 569 578 589 591 593 595 601 616 623 625 627 628 629 630 631 632	111 552 578

TABLE VIII

SUMMARY OF RESULTS FOR TEST 2C,
MODEL D, DETAILED DAMAGE

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
1	10	56 68 80 112 114 118 126	---	---
2	12	106 132	---	---
3	14	62 82 111 135 256	---	---
4	16	49 50 108 124 134 255	---	---
5	18	116 117 133 258	68	68
6	16	---	---	---
7	18	---	66	66
8	16	79 81 113 129	460	460
9	14	---	---	---
10	16	---	462	462
11	14	---	---	---
12	16	---	---	---
13	18	61 105 107	70	70
14	16	54	---	---
15	18	52 115	---	---
16	20	---	56	56
17	18	63	430	430
18	16	---	---	---
19	18	---	58 432	58
20	16	64	432	432
21	14	---	---	---
22	16	---	---	---
23	18	---	62 255 434	62 255
24	16	254	64 78 81 82 187 434	81 434
25	14	---	64 78 79 82 105 254 436	78 79 254
26	12	55	64 77 82 105 436 477 479	64 479

TABLE VIII (Continued)

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
27	10	85	77 82 105 436 477 481	77 436 481
28	8	---	---	---
29	10	131	54 80 428 475 477	54 80 475 477
30	8	73 126	52 75 82 428 438	52 75 428 438
31	6	---	55 473	55
32	4	---	---	---
33	6	---	427 429	427 429
34	4	---	---	---

TABLE IX

SUMMARY OF RESULTS FOR TEST 3B, MODEL A, SIMPLE DAMAGE

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
1	10	---	510	510
2	8	---	---	---
3	10	---	---	---
4	11	49 114 134 136	110	110
5	10	130 132	128	128
6	8	---	---	---
7	10	135	---	---
8	11	---	---	---
9	12	---	---	---
10	13	116 133	66	66
11	12	56	---	---
12	13	111	460 462	460 462
13	12	52 55 82	424 432	424 432
14	10	80 113	58	58
15	8	---	528	528
16	6	---	---	---
17	8	81 254	434	434
18	6	---	436	436
19	4	---	---	---
20	6	79 256	---	---
21	8	61 129 197 213	52 438 482	52 438
22	6	62	---	---
23	8	63 107 115 257	109 127 437 582	127 437 582
24	6	---	109	109
25	4	---	---	---
26	6	---	---	---
27	8	51	78 111	78 111
28	6	---	60	60
29	4	54	532	532

TABLE X

SUMMARY OF RESULTS FOR TEST 3B, MODEL D, DETAILED DAMAGE

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
1	10	56 68 112 114 118 136	---	---
2	12	132 256	---	---
3	14	62 134	---	---
4	16	49 80 116 135	510	510
5	14	---	110	110
6	12	130	112 128	112
7	10	---	566	566
8	8	---	---	---
9	10	---	---	---
10	12	---	---	---
11	14	---	114	114
12	12	50 82	568	568
13	10	---	---	---
14	12	---	---	---
15	14	124	---	---
16	16	258	---	---
17	17	67 117	---	---
18	18	111 254	---	---
19	19	---	530	530
20	18	---	528 532 534 574	528 532 534
21	17	55 64 73 97 107 113 126 129 143 255 257	118 120 256 552 574	120 256
22	16	115 125	116 117 118 138 257 536 552 574 592	117 118 536
23	14	51 63 85 123 131 133 141	56 58 79 81 85 107 115 119 137 257 279 430 476 499 535 573 574	73 107 115 279 476 573 574

TABLE X (Continued)

Iteration No.	Load	Buckled Elements	Overstressed Elements	Failed Elements
24	12	105	55 56 57 58 69 71 75 78 113 119 197 429 430 467 471 473 535 571	71 113 119 535 571
25	10	---	55 58 75 78 79 80 105 111 121 197 429 430 467 471 473 478 569 575	105 111 467 473 569
26	8	---	58 75 77 78 80 109 197 429 430 471 533 567	58 109 471 533 567

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